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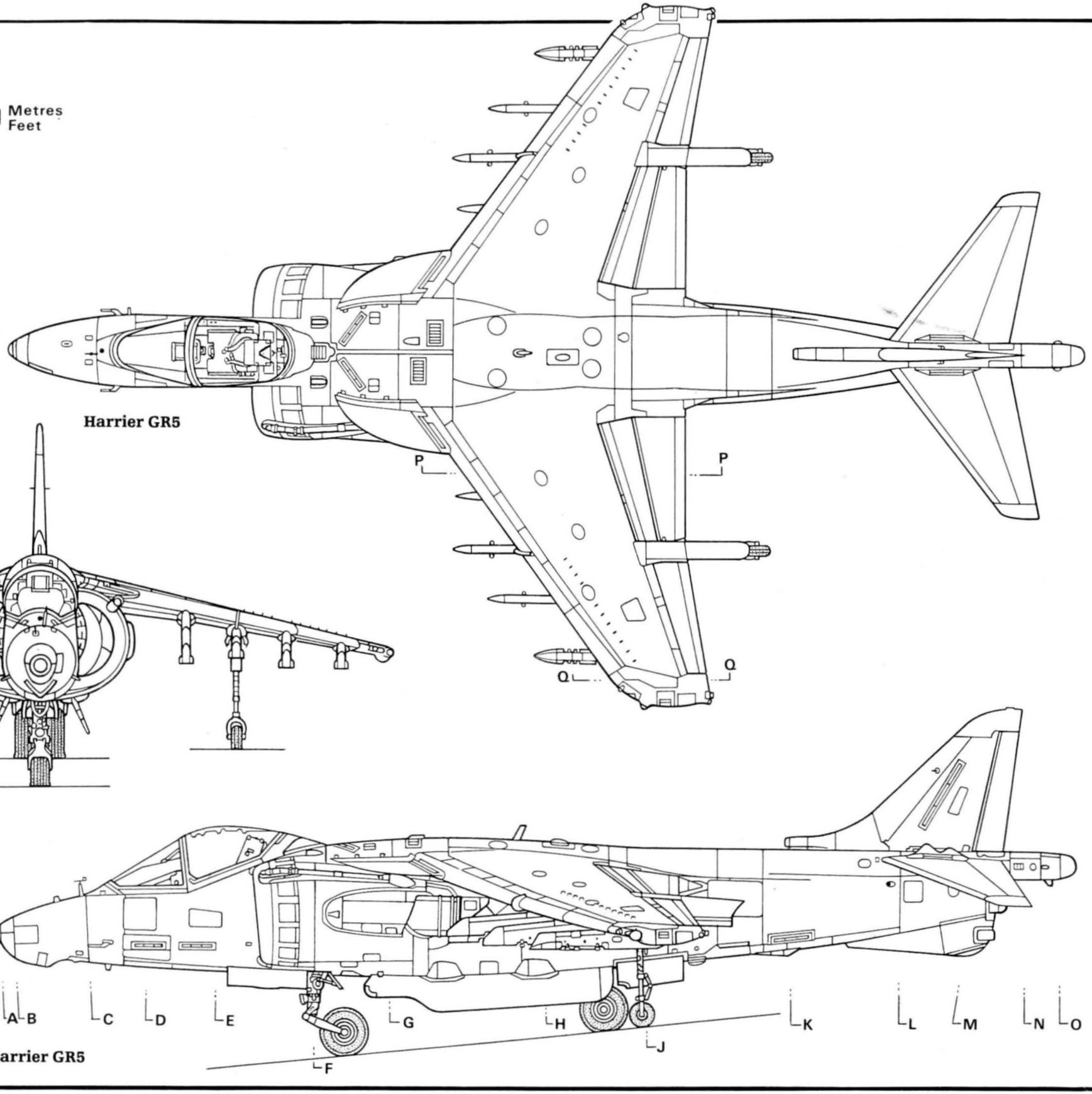
HARRIER

DENIS J. CALVERT

Drawings by Mike Keep

Scale

Metres
Feet



Harrier GR5

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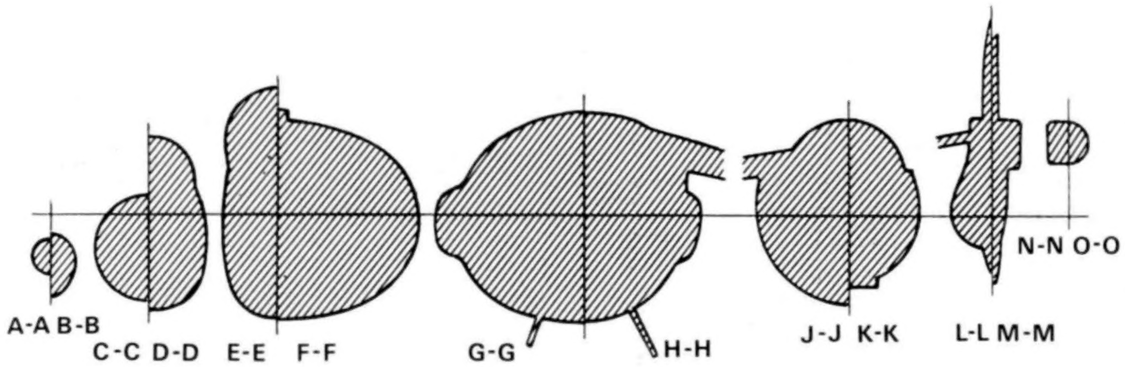

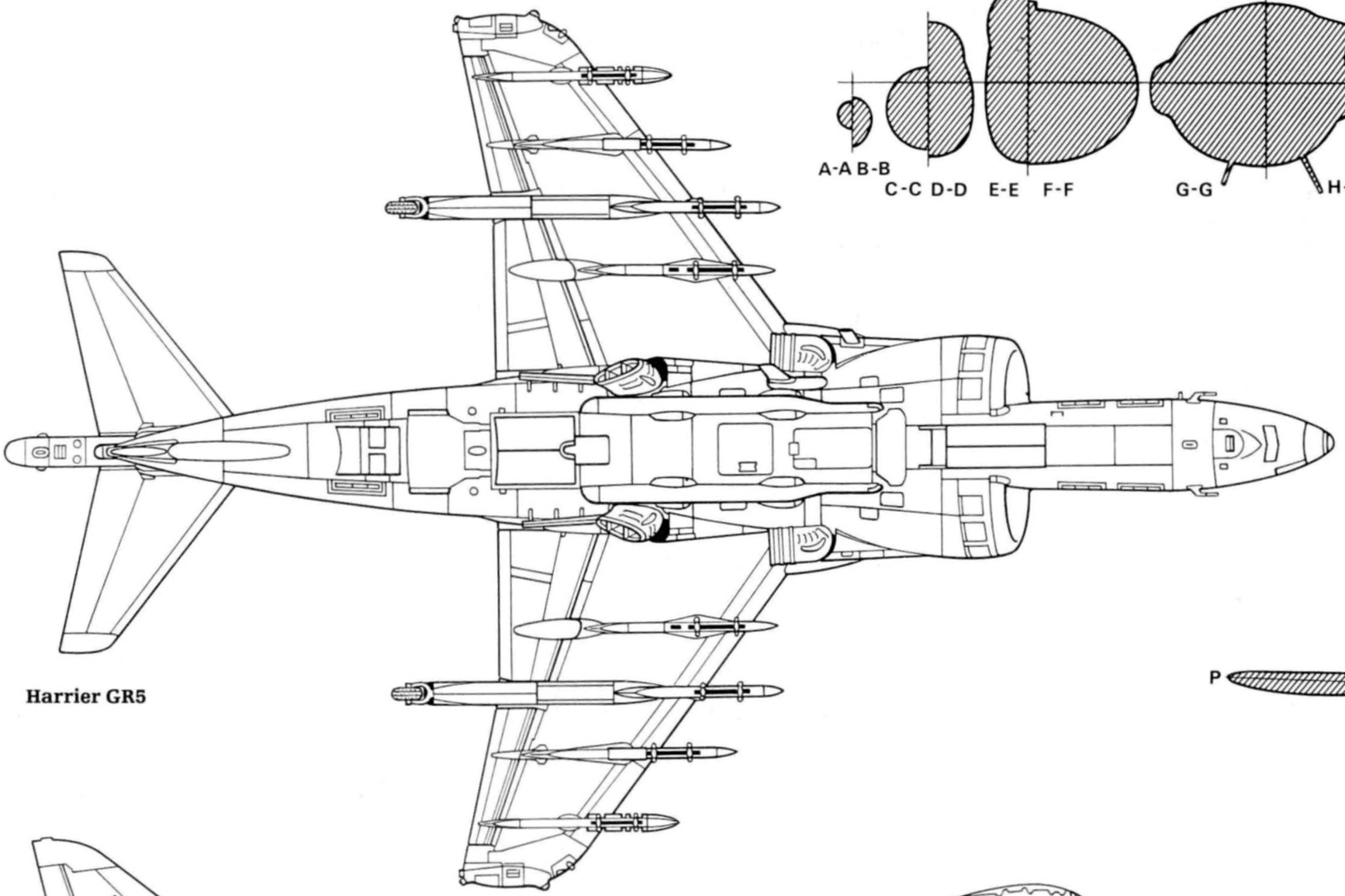

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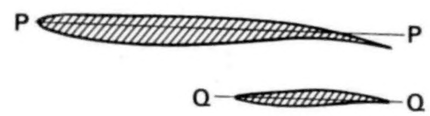

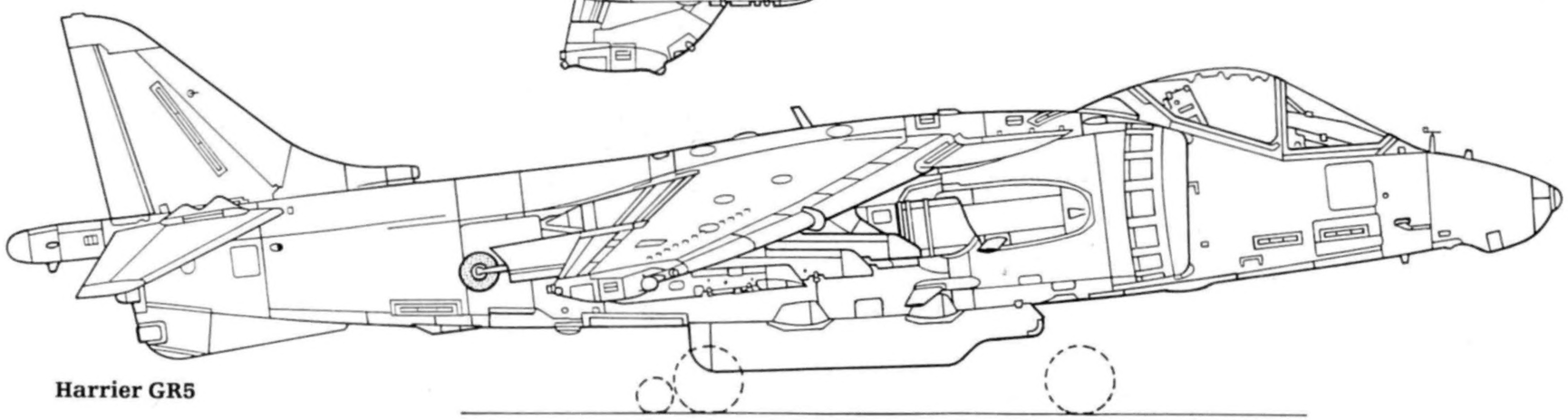

Harrier GR5

aircraft illustrated **SPECIAL**

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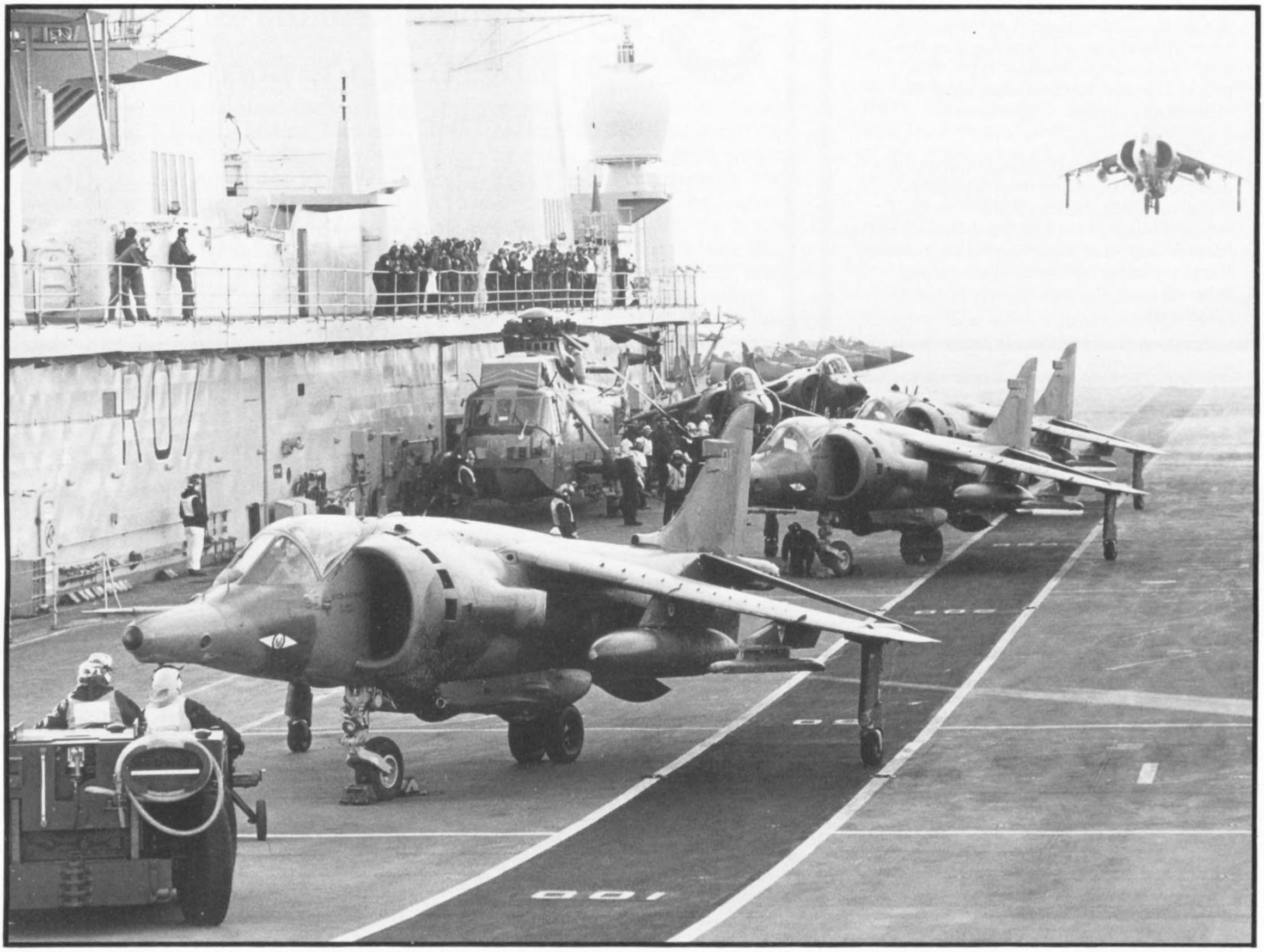

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LONDON

IAN ALLAN LTD

First published 1990

ISBN 0 7110 1886 3

Published by Ian Allan Ltd, Shepperton, Surrey; and printed by Ian Allan Printing Ltd at their works at Coombelands in Runnymede, England

Front cover:
The Harrier GR5 represents a considerable increase in capability over the earlier GR3 which it replaces, and appropriately No 1 Squadron was the first to convert to the new type. This picture shows the menacing head-on view to advantage. *Allan Burney*

Below:
Exercise 'Hazel Flute' in September 1989 was the first occasion on which RAF Germany GR5s deployed 'into the field', when aircraft of No 3 (F) Squadron operated from Flying Sites 'Eberhard' and 'Jubilee'. Here, a Harrier makes a short rolling take-off from the rain-covered road at Eberhard.

Contents

Introduction

Introduction

Before the Harrier's introduction into service, military planners were frankly sceptical about the practicality of V/STOL jet fighter operations. The attractions of flying from dispersed sites were beyond question; the current generation of jet fighters was increasingly tied to long concrete runways, whose continued existence in a 'hot' shooting war in Europe was questionable. But the doubts remained. Even if the Harrier could take off and land vertically, what were the performance penalties associated with carrying around such a large engine, optimised for take-off but over-powered for the rest of the sortie? And would not the advantages of dispersed sites be negated by the logistics of the operation, as the RAF did not possess a single heavy-lift helicopter?

Today, these arguments have lost their validity. The 500 Harriers which have rolled off the production lines are adequate proof of the practicality of V/STOL operations, and the two RAF Germany squadrons realistically represent the only 'survivable' attack force available to NATO's 2ATAF in Central Europe. At sea, the Sea Harrier's exploits in the South Atlantic in 1982 made it perhaps better known even than the land-based Harrier from which it was developed. With the demonstration of the technical validity of the V/STOL concept, it is only surprising that other countries' air forces have not joined the lead of the RAF and the US Marine Corps in putting the Harrier into their inventories. The ultimate self-delusion is that every air force general asserts he has the necessary offensive airpower to crater the enemy's runways and render them unusable, while believing his own 8,000ft strips of concrete to be inviolate. Hardened Aircraft Shelters (HAS) protect his aircraft, but one well-placed weapon can still transform the runway into two 4,000ft strips, separated by a large crater. What price Mach 2 performance then?

In practice, the 'V' of V/STOL has shifted to give STOVL, the acronym which more accurately reflects Harrier operations — Short Take-Off and Vertical Landing. To understand the Harrier's essential flexibility, take the case of the 'big wing' GR5, the latest of the line. Powered by a Pegasus 11-61 with 23,800lb of thrust (the engine version to be fitted to production aircraft from 1990), the aircraft is clearly unable to take-off vertically (ie relying completely on engine lift) at any weight approaching 23,800lb. To be capable of vertical take-off, fuel and/or warload must be reduced to a figure well below this, although a worthwhile payload can still be carried and the importance of the basing flexibility is not to be underestimated. At the other extreme, using a normal runway and a rolling take-off, the Harrier can launch at an all-up weight of over 30,000lb. Between these two options is the short rolling take-off, where the aircraft rolls forward with the engine nozzles pointing rearward to build up airspeed, then rotates them downwards to unstick. The Harrier's wing produces an extra 7,000lb of lift at low forward airspeeds, which allows the aircraft to take-off at an all-up weight of 30,000lb at no more than 50-70kt and in a distance of just a few hundred metres. With such performance, any straight stretch of country road becomes a Harrier runway, and recoveries can be made vertically when the ordnance has been expended and the fuel burned off by a half-hour sortie over the battlefield. It is this style of operation which gave the Harrier its 'jump jet' appellation. Once in the air, the Harrier has other intrinsic advantages, such as the fuel economy of its Pegasus turbofan, a mainly specific excess power and a low infra-red signature — the results of employing a non-afterburning engine.

The Sea Harrier has made possible a similar revolution in carrier operations. While the US Navy continues to build (albeit at a rate of only one every four years) 80,000-ton leviathans, the Royal Navy has shown the way towards simplification. The angled deck and the steam catapult (both British inventions) were replaced by the Sea Harrier and the ski-jump (again from the same stable), this time in a ship of less than 20,000 tons. The result is affordable airpower at sea. Not only are the cost and complexity of the carrier operations reduced (only the USA and Russia are really in the attack carrier league now), but operational flexibility is increased. F-14 Tomcats and AWG-9 or not, a USN attack carrier has predictably to steam into the wind to give the requisite wind-over-deck for launching its aircraft, which can provide no air defence of any kind when the ship is tied up in dock. Spain, India and (soon) Italy have followed the Royal Navy into Harrier-carrier operations, and it is arguable that the Harrier has made more of a mark at sea than with land-based air forces.

Even smaller ships could be made Harrier-compatible using British Aerospace's (BAe) computer-controlled 'Skyhook' crane launch and recovery system. Further development of the Harrier line will almost certainly lead to a supersonic V/STOL fighter by the end of the century, although it will probably come from St Louis, Missouri rather than from the Harrier's Kingston-upon-Thames birthplace. While such a type's design will probably have relatively little in common with the current aircraft, it will certainly benefit from the 20 years' V/STOL service experience of the Harrier and Harrier II.

ACKNOWLEDGEMENTS

Flt Lt Janette Barr, RAF Wittering
Flt Lt Ian Black
Phil Boyden
Greg Ferguson, BAe Kingston
TN Jorge Flethes, *Escuadrilla 008*
Peter Guiver
Michael Hill, CPRO RAF Strike Command
Martin Horseman
John Hutchinson, Rolls-Royce
Flt Lt Ray Innes, RAF Gütersloh
Jon Lake
Frank Mormillo
Michael O'Leary
Bill Sides
Cdr Vic Sirett, RNAS Yeovilton
Mike Stroud
Sqn Ldr Morag Urquhart, British Forces Germany
Jurgen Valley

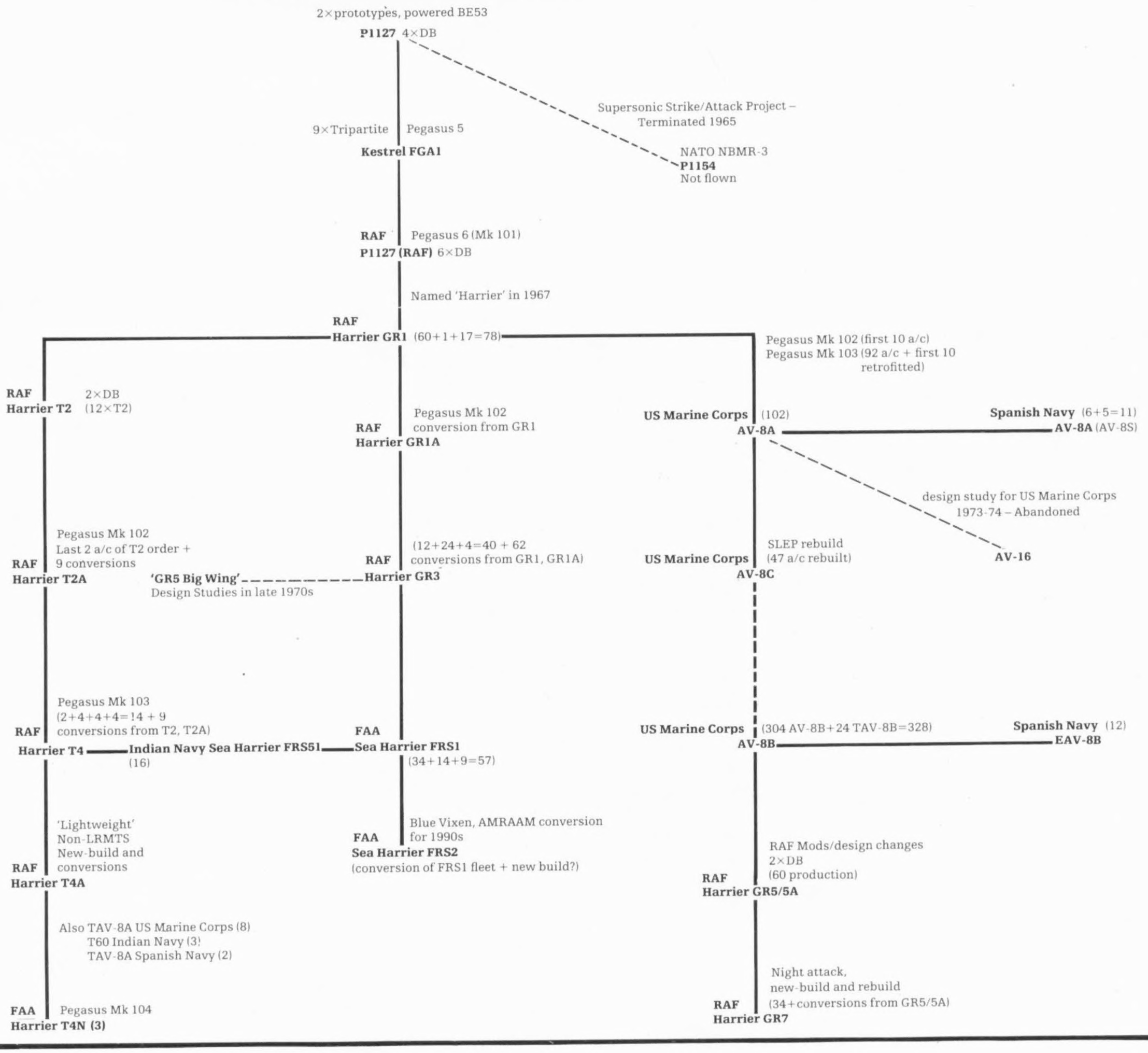
In the Beginning

From P1127 via Kestrel to Harrier GR1

The Harrier – or at least the prototype and development aircraft which led to the present-day Harrier family – has now been flying for nearly 30 years. Between the P1127 which made its first tentative tethered flights at Dunsfold in October 1960 and the big-winged, composite Harrier II which is today re-equipping RAF and US Marine Corps squadrons, there is a history of continual development and improvement. This book is intended as a development and service history of the Harrier and its progenitors, and does not intend to go too deeply into the politics which (inevitably?) surround any major military programme today. But the story is a complex and an interesting one, and a tribute to the Hawker design team which opted to design and produce an aircraft which went against the trend.

The following table, brief and outline though it may be, illustrates the basic genealogy of the complete Harrier family.

THE HARRIER FAMILY



Above:
Surprisingly few photographs exist of the first prototype P1127 making its initial, tethered flights in the autumn of 1960. Here, XP831 hovers just a few feet above the ground at Dunsfold; the aircraft is stripped of all unnecessary items, including nose probe, undercarriage doors and airbrake. *BAe EXP 344/60*

Below:
XP831 made the first flights by a fixed-wing jet V/STOL aircraft from a carrier, when Bill Bedford and Hugh Merewether flew from HMS *Ark Royal* in Lyme Bay on 8 February 1963. These flights proved that carrier-borne V/STOL was practicable, but the regular basing of Harriers on board ships did not happen until the advent of the Sea Harrier in 1978. *BAe*

The company which started development of the line of design studies which led to today's Harrier was Hawker Aircraft Ltd at Kingston-upon-Thames, which had met with considerable success in the 'fifties with the Hunter fighter. This company merged into Hawker Siddeley Aviation (HSA) in 1963, which in turn in 1977 got together with the only other major British aircraft manufacturer, British Aircraft Corporation, to form the nationalised (but now re-privatised) British Aerospace (BAe). A similarly complex situation arises for the engine manufacturers. The company responsible for the design and production of the engine used in the prototype P1127 (the BE53, which was later called Pegasus) was Bristol Siddeley Engines Ltd at Bristol. Subsequent industry reorganisations were to see it merge with its arch rivals from Derby to become Rolls-Royce Ltd (Bristol Engine Division), and more recently simply part of Rolls-Royce plc. The role played in the Harrier story by the Pegasus cannot in any way be overstated, and each significant improvement in the aircraft's history has been primarily the result of a version of the Pegasus offering improved thrust while keeping the same overall dimensions. For this reason, and to keep together details of the various marks of engine fitted to different Harriers, a separate short chapter has been included later in this volume on the Pegasus.

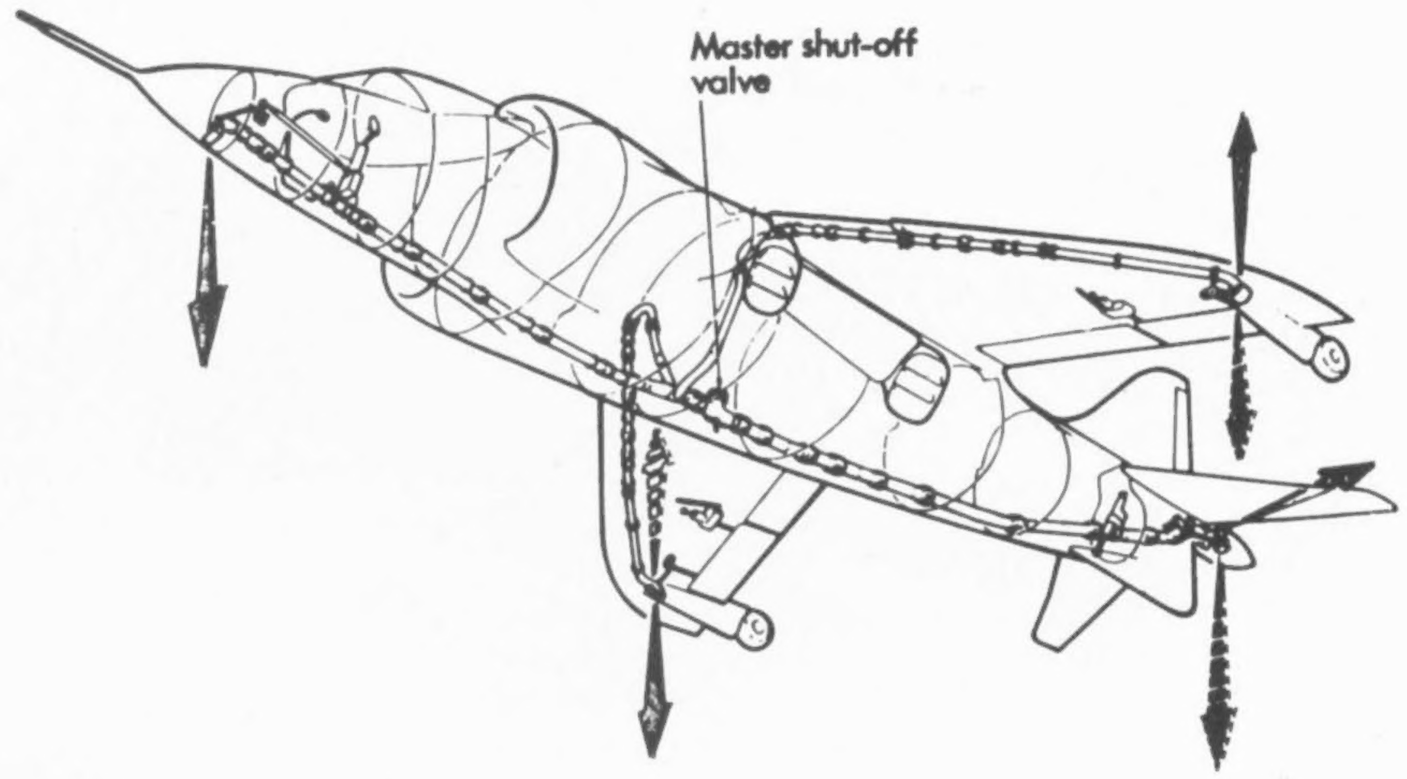
The background of the P1127 project is quite international. While the basic idea for the revolutionary engine design came from Frenchman Michel Wibault, it was Bristol Aero Engines which took over and developed the idea into the BE53. The exhaust, rather than being at the rear of the engine as normal, was through four rotating elbow nozzles, with the fan thus discharging through the front pair of nozzles as well as supercharging' the HP spool. This arrangement allowed all the engine thrust to be vectored downwards when required, while bleed air for control purposes in V/STOL flight (when a low forward airspeed leads to the ineffectiveness of conventional aerodynamic control surfaces) was to be taken from the fan stage and ducted to valves at the nose, rear fuselage and wingtips. The design of the BE53 as it had evolved by 1958 contained all the basic features of the Pegasus which remains in production today as the powerplant

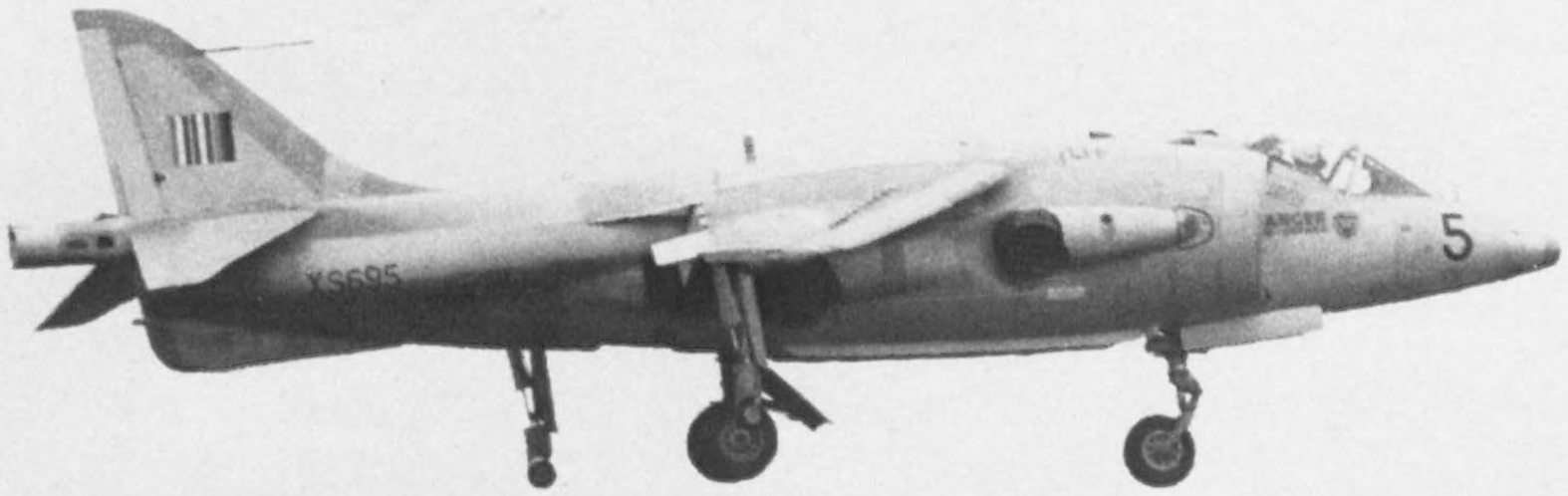
for the Harrier family. Hawker Aircraft became involved with the BE53 in mid-1957, and was able to use this powerplant with its 'four post lift' as the basis for a whole range of studies for V/STOL aircraft. By late 1958, Hawker had evolved a P1127 configuration which looks very like today's Harrier in all its principal design points, based around the BE53.

In early 1959, Hawker was still without any official backing from the Ministry of Supply (MoS). for its projected aircraft, although the P1127 design had progressed to the point where manufacture of a prototype had started as a private venture. Hawker had, up to this point, been very involved in its submissions to meet OR339, the RAF's Canberra replacement requirement which was finally awarded to BAC for its TSR2. Construction of the engine, meanwhile, had commenced in the summer of 1958, and bench running of the first BE53 started in September 1959. MoS funding for two prototype P1127s came in late 1959, under ER204D. Hawker's design for the P1127 always included

Above:
A superb in-flight shot of XS688, a Tripartite Kestrel FGA1. This was the first Kestrel to fly, and as seen here still lacks the extended-span 'kinked leading-edge' tailplane and the wing vortex generators. These were retrofitted to XS688, and the changes incorporated on the line to following aircraft. *BAe P1127/114/64*

Reaction control system
(Courtesy BAe Kingston)





Above:
XS694 and XS695, two Kestrel FGA1s, are seen hovering above a grassy surface. This photograph was probably taken in the summer of 1965, when the Tripartite Squadron was making use of a number of disused airfields and country areas near West Raynham to demonstrate dispersed site operations. *BAe*

provision for its development into a military role, with suitable airframe stressing and provision for a payload and external armament, however far in the future this must have seemed on the projected 11,000lb thrust of the BE53.

The Kingston design office, still under the legendary Sir Sydney Camm's direction, was clearly constrained to produce a design in which several novel features would need to be incorporated. In particular, the four-nozzle engine design moved the C of G of the engine forward compared with a conventional engine, forcing the designers to balance this by installing avionics in the rear fuselage. With the engine exhausting close to where the main wheels would be if a conventional design of undercarriage were to be adopted, the decision was made to go for a 'bicycle' arrangement, as used by Boeing's jet bombers of the period.

When delivered to Dunsfold in September 1960, the BE53 was rated at only 11,300lb thrust, so the P1127 was lightened for its initial tethered flying by the removal of all unnecessary items, these including the pitot head and airbrake. In this state and with minimum fuel, it had an excess of thrust over weight of 1,300lb at take-off, a performance considered marginal. Bill Bedford was scheduled to make the initial flight, with the aircraft tethered by the outriggers, nosewheel leg and under the rear fuselage, and he achieved a 'first hover' on 21 October 1960. Flight trials then progressed to untethered hovering, and on to conventional take-off and landing on 13 March 1961. The summer saw XP831 joined in the test programme by XP836, while the whole project got a fillip from the agreement by the MoS to fund four more Development Batch (DB) aircraft, and to support financially the Pegasus engine. Transition from vertical to horizontal flight was first achieved in September 1961 by XP831, which demonstrated accelerating and decelerating transitions following some design changes to the reaction control system. Subsequent trials explored the high-speed end of the envelope, and supersonic flight (in a dive) was achieved on 12 December 1961. Experience with the first two prototypes gave rise to a number of changes on the third aircraft, which featured, among other differences, revised wingtip fairings.

Above:
Wide-angle lenses can distort — but this nose-on shot of an early production Harrier GR1 emphasises the P1127's transformation into a warplane, with pylons (only two fitted here) and a nose oblique camera — not to mention a camouflage paint scheme. Mounted under-wing appear to be two 330gal ferry tanks, while extended ferry wingtips are fitted.
BAe 713484

More importantly, a new wing was deemed necessary and work started on the current swept (rather than delta) planform for application to future aircraft.

On 8 February 1963, XP831 undertook the first P1127 trials at sea, when it made a series of flights from HMS *Ark Royal* in Lyme Bay. Flown by Bedford and Merewether, the five days of trials revealed no particular problems, and underlined the suitability of V/STOL aircraft for carrier operations. It is probably an understatement to say that the subsequent significance of these trials was lost to all but a few of those present on board the *Ark* at that time.

Interest in the viability of an operational V/STOL fighter crystallised with the agreement in 1963 by Britain, the USA and West Germany jointly to fund the production of nine developed P1127s to form a tri-national squadron. XP984, the fourth and last of the DB P1127s, served as the prototype for the Kestrel. This aircraft was the first to receive the new swept wing, and featured an uprated Pegasus 5 engine of 15,500lb thrust, with intakes having inflatable lips. The fuselage was lengthened by 9in, the tailplane given increased span and the reaction control system further modified. Provision was made for external loads, perhaps reflecting the fact that for the first time the Pegasus 5 had a thrust rating which made a warload a practical possibility; two underwing pylons were fitted, together with a nose-mounted port oblique camera.

The first aircraft (XS688) for the Tripartite Evaluation Squadron flew on 7 March 1964, although the name Kestrel FGA1 was not officially adopted until 30 September, and by Christmas of that year six of the nine were flying. Pilot conversion on to the type started in 1964 and continued into the early part of 1965, when the aircraft were being delivered to RAF West Raynham, the Tripartite Squadron's home base. The unit officially began operations on 1 April, on which date Kestrel XS696 was inauspiciously destroyed in a take-off accident, but the following eight months saw around 600hr of flying and over 900 sorties being accumulated by the three nations' pilots. Flights were made from the runway and, more importantly, from a number of dispersed sites and using a variety of surfaces for V/STOL operation – including natural grass. Opinions were unanimous that the Kestrel represented a viable concept, and that developed V/STOL fighters would be capable of operating in weather minima similar to those of conventional aircraft.

At this point, mention must be made of the most ambitious P1127 development, even though in the event it led nowhere. In 1960-61, NATO was formulating a requirement for a supersonic V/STOL strike/attack fighter, which finally emerged as NBMR-3. Candidates for this ambitious (V/STOL take-off, 250 mile radius of action, lo-lo at Mach 0.9 with a 2,000lb warload) requirement were the Dassault Mirage IIIV and a developed vectored thrust Kingston project which emerged as the P1154. To cut a long story short, the two designs were judged joint winners in the NATO competition (shades of the Caucus Race in *Alice in Wonderland*), but the P1154 never seemed likely to lead to hard foreign orders, and became a purely national project before being shelved completely.

The cancellation of the P1154 in January 1965 was softened only somewhat by the announcement that the Kestrel was to be developed further to give an operational aircraft for the RAF, to enter service four years later. Initial reaction from the RAF and at Kingston (where the kudos of introducing the first supersonic V/STOL aircraft to service had seemed an important accolade for a design team with many other 'firsts' to its credit) was less than enthusiastic. Notwithstanding, development got under way on the design, which was initially known as P1127 (RAF). If the Kestrel had represented a 50% redesign over the baseline P1127, the P1127(RAF) (which was to become the Harrier GR1) was virtually a new aircraft.

At the centre of the P1127(RAF) was the projected Pegasus 6 (later known as the Mk 101), rated at 19,000lb. To meet the mass flow requirements of this engine, the intakes were redesigned, while six (later increased to eight) 'blow-in' auxiliary inlets were added on each side. The wing was redesigned with vortex generators, fences and tip

Above:
The scene at St Pancras coal yard in May 1969, with Harrier GR1 XV741 — one of two participating in the *Daily Mail* Transatlantic Air Race — preparing to take off. Fitted are the now-extinct extended ferry wingtips, the unlovely fixed refuelling probe and two 100gal drop-tanks. *BAe 124549*

Below:
The first nose badge to be adopted by the Harrier Operational Conversion Unit (later No 233 OCU) was the highly appropriate one of a grasshopper. *M. Horseman*

extensions. Whilst retaining the basic geometry of the P1127, the new aircraft's undercarriage had changed to facilitate operation from rough surfaces, with main gear doors which closed with the undercarriage down. Autostabilisation was considered desirable for squadron use, and a Marconi system was fitted, initially two-axis but later extended to all three. Many of the avionics systems designed for the P1154 were to be incorporated, both to capitalise to some degree on the huge engineering effort which had gone into P1154 and as a political sop following the programme's termination. Most importantly, the P1127(RAF) was to have a worthwhile warload, for which five pylons were fitted. No fixed gun armament was envisaged, but provision was made for two 30mm Aden cannon with 130 rounds per gun, housed in under-fuselage gunpods, aerodynamically designed to improve airflow in the hover. Six Development Batch (DB) aircraft were ordered to meet the tight timescale to service in 1969, and the first (XV738) flew on 28 December 1967. By this time, the name and designation Harrier GR1 (ground attack/reconnaissance) had been allocated, continuing the series of 'H'-named fighters which had made Kingston famous.

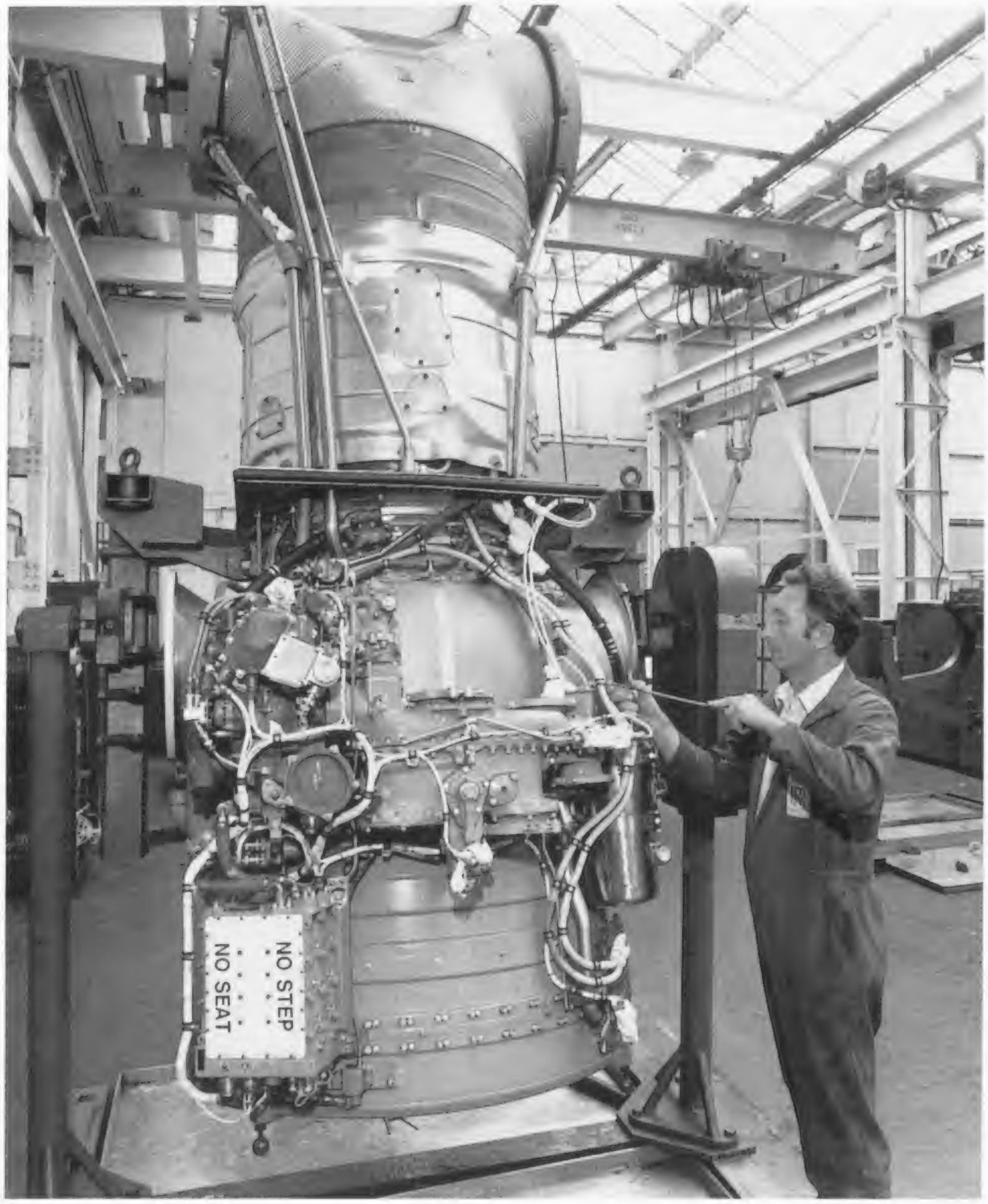
The Power Behind the Throne

The Pegasus Turbofan

Probably no aircraft before has had its development history so closely tied to the increasing thrust of its engine as has been the case with the P1127/ Kestrel/Harrier/Harrier II. Without going into too much detail, the Pegasus is an axial-flow twin-spool dry (ie non-afterburning) turbofan, with spools rotating in opposite directions to minimise gyroscopic coupling. Taking the Mk 103 (installed in the Harrier GR3) as typical, the engine has a bypass ratio of 1.29:1 at V/STOL rating, and has a design airflow of 440lb/sec. The low pressure (LP) and high pressure (HP) compressor systems are co-axial, with a three-stage fan driven by a two-stage LP turbine. The eight-stage HP compressor is driven by the two-stage HP turbine, and is supercharged by the fan. Two pairs of exhaust nozzles are fitted, these being rotatable and positioned symmetrically on either side of the engine. Bypass air from the fan is exhausted through the front (cold – 150°C) nozzles, while gases from the combustion chamber passing through the HP and LP turbines discharge through the rear (hot) nozzles. The total thrust is divided almost equally between the front and rear nozzles, which by rotation can turn the exhaust flows through nearly 100°, and the centre of thrust passes virtually through the centre of gravity of the aircraft, regardless of nozzle position. The nozzles themselves are fabricated from sheet steel, and incorporate two aerofoil section vanes across the throat. Control of the nozzles is by a nozzle actuation system (NAS) which uses air from the sixth stage HP compressor to power an air motor which drives the four nozzles synchronously via a system of shafts, gears and chains. Nominal nozzle movement is from 0° (fully aft) through 100°, at which setting the engine contributes a negative (decelerating) thrust approaching 4,000lb. When the Pegasus made its first ground runs in 1959, it achieved a thrust of 9,000lb, which was clearly insufficient for any flying of the P1127, but the Pegasus 2 and 3 increased this via 11,300lb to 14,000lb. It was with a Pegasus 3 that the first VTOL transitions were made in 1961, although this performance was achieved at the cost of a time between overhauls of only 30hr. Considerable redesign led to the Pegasus 5, which was basically a 3 with a third fan stage, and with the inlet guide vanes deleted. This engine delivered 15,500lb thrust, and was fitted to the final DB P1127 (XP984) and to the nine Kestrels, having an initial time between overhauls of 50hr.

Below:
A Pegasus Mk 105 turbofan, fitted with Digital Engine Control System (DECS) seen prior to being fitted to a Harrier GR5. The Mk 105 variant produces 22,000lb (97.8kN) thrust, and is the engine being fitted to current production Harrier GR5s and AV-8Bs. *Rolls-Royce*

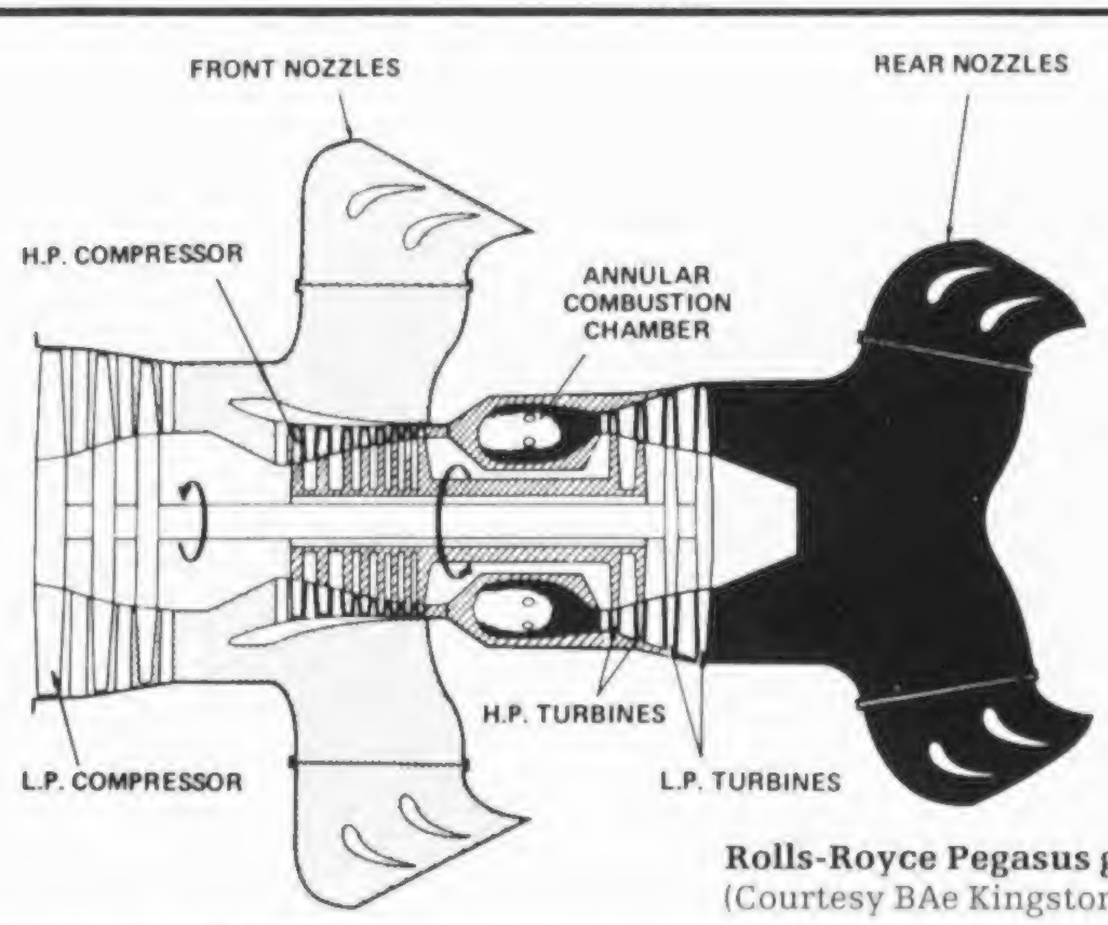
The decision to develop the P1127-(RAF) with an uprated production engine led directly to the Pegasus 6 of 19,000lb thrust. This increase was achieved by the acceptance of an increase in turbine entry temperature, requiring an air-cooled second-stage turbine. A revised combustion system was incorporated, involving the use of water injection to maintain the thrust of the engine to ISA plus 15°C, and a new titanium fan. A Lucas gas turbine starter is fitted to the Pegasus; the aircraft is thus completely self-sufficient as regards starting, while the unit can also double as an APU. It was with the Pegasus 6 that the Harrier GR1 first entered RAF service, and this engine had a service life of 300hr. Three thrust ratings were specified for the Mk 6 — 'short lift' power for short periods (15sec) at take-off, 'normal lift' for longer periods (up to 150sec) of hovering, and 'maximum thrust' for conventional flight. To prevent the exceeding of permitted temperatures at any of these ratings, an electrical jet pipe temperature limiter is fitted, which automatically limits the temperature as a function of the rating. At take-off and with nozzles rotated downwards, the 'short lift' datum is used, the allowable jet pipe temperature being increased to 'short lift wet' with the selection of water injection. Following take-off and as soon as the nozzles are in the rearward position and the undercarriage is up, the jet pipe temperature is automatically limited to the 'maximum thrust' value, which allows the aircraft to be flown at full throttle without the pilot having to consult the engine instruments. This system of rating, for V/STOL and conventional flight, has been used for all subsequent marks of Pegasus.



Above:
A Pegasus Mk 105 on final assembly at the military engine factories of Rolls-Royce at Filton, Bristol. *Rolls-Royce E287249*

The Pegasus in the Harrier clearly operates in an environment somewhat different from that of a conventional jet fighter. It is called upon to produce maximum thrust at least twice in each sortie, running at high operating temperatures for both take-off and landing. A 'life recorder' is thus fitted to the engine, to record the amount of turbine creep life used as a function of jet pipe temperature and lift ratings. Life recorder counts thus provide a secondary method of assessing engine condition, being used in addition to the normal 'engine hours since overhaul'.

The Pegasus 6, also known as the Mk 101, was followed by the interim uprated Pegasus 10 (Mk 102) of 20,500lb thrust. Further development led to the Pegasus 11 giving 21,500lb, variants of which power all current service and production Harriers. Redesigning the fan to give a higher mass flow and an increased pressure ratio allowed higher turbine entry temperatures, while the water injection system was changed to introduce water into the HP turbine cooling air as well as the combustion chamber. RAF Harriers built with the Pegasus 11 Mk 103 were designated GR3, while earlier GR1 and GR1A retrofitted with the engine were given the same designation. It is a common misconception that the distinguishing feature of the Harrier GR3 was the



Rolls-Royce Pegasus gas flows
(Courtesy BAe Kingston)

Above:
The Harrier Servicing Flight (HSF) at RAF Gütersloh is responsible for the second-line servicing on RAF Germany Harriers, with deeper repairs carried out at No 431 MU at Brüggen. As seen here (HSF at Gütersloh, 26 June 1981), the Harrier wing has to be removed from the aircraft in order to take out the engine. *Author*

fitting of the LRMTS in the modified nose. Not so — the installation of the uprated Pegasus Mk 103 is the sole criterion for the application of the GR3 designation, although it is true that the laser nose was not fitted to earlier marks, for reasons which certainly included the lack of the necessary installed thrust.

Whilst the Pegasus' thrust vectoring was designed for take-off and landing, the same mechanism can be used in flight to allow the aircraft to decelerate quickly or to decrease its turn radius. Development of Vectoring in Forward Flight (or VIFFing, as it is known) was largely carried out by the US Marine Corps. Engine modifications to allow service aircraft to be cleared for VIFFing were limited, but included an increase in the size of the nozzle drive chains. The result is an effective manoeuvre to dislodge an attacker from behind a Harrier, and one which takes direct advantage of the type's design features.

Power for the Sea Harrier is provided by a navalised version of the Pegasus 11 designated Mk 104. This variant features an aluminium alloy (rather than a magnesium alloy) fan and casing, together with other corrosion-proofing to permit continuous operation in a saline atmosphere. Static thrust of the Mk 104 is the same as that for the Mk 103, while broadly similar engines are designated Mk 150 for the Spanish Navy AV-8A and Mk 151-32 for Indian Navy Sea Harriers. Fitted to AV-8A/AV-8C Harriers flown by the US Marine Corps, the engine is referred to as F402-RR-402, this reflecting both US service designations and the fact that Pratt & Whitney partners Rolls-Royce on the Pegasus programme.

All these thrust and reliability enhancements over 30 years have been achieved virtually without changing the overall dimensions of the engine, and more particularly without increasing the fan diameter. To date, Rolls-Royce has produced over 700 engines, which have accumulated half a million hours in service. Even so, there is still considerable growth potential beyond the Pegasus 11. Power for the latest Harrier II versions is provided by the Pegasus 11-21, also known as Mk 105 to the RAF or F402-RR-406 in US Marine Corps service. Pratt & Whitney has a 25% stake in the production of this engine to meet US Marine Corps orders. This engine was designed primarily to have maintainability and reliability improvements over previous versions, with an overhaul life of 1,000hr and hot section inspection required at 500hr. Viewed from the exterior, the Mk 105 has the front exhaust nozzles cut off at right angles to the fuselage. These 'zero scarf' nozzles contribute extra thrust, while the engine runs slightly colder than previous versions, and a Digital Engine Control System (DECS) is fitted. This system, developed by Smiths Industries, controls fuel flow to the engine in the complex operating conditions of V/STOL operations, and replaces the original hydromechanical fuel control which was designed in the 1960s. Further developments will see the Pegasus 11-61 rated at 23,800lb thrust as the result of a new fan and improved turbines. This version again has the same overall dimensions as earlier engines, and will thus be fitted into later production AV-8B (as the F402-RR-408). The 11-61 has not yet been ordered for RAF GR5, but is a strong probability for any follow-on batches beyond the 96 aircraft ordered to date, as well as being a retrofit option for earlier Harriers. Further dramatic thrust increases have been demonstrated on the test bed by using a burner system in the front (cold) exhaust nozzles — a form of after-burning. This system, proposed for the BS100 engine for the P1154, is known as Plenum Chamber Burning (PCB). Its application is more realistically proposed for more advanced engines for later versions of the Harrier family, and is unlikely to be seen on a flying Harrier of the current generation.

Engine		Aircraft		Operator
Series	*Designation*	*Series*	*Designation*	
Pegasus 11	Mk 103	Harrier	GR Mk 3	Royal Air Force
Pegasus 11	F402-RR-402	Harrier	AV-8A	US Marine Corps
Pegasus 11	Mk 150	Harrier	AV-8A Matador	Spanish Navy
Pegasus 11	Mk 104	Sea Harrier	FRS Mk 1	Royal Navy
Pegasus 11	Mk 151-32	Sea Harrier	FRS Mk 51	Indian Navy
Pegasus 11-21	F402-RR-406	Harrier II	AV-8B	US Marine Corps
Pegasus 11-21	Mk 105	Harrier II	GR Mk 5	Royal Air Force
Pegasus 11-21	Mk 152-42	Harrier II	EAV-8B	Spanish Navy

Harrier into Service

GR1 through GR1A to GR3 and the Falklands

As can be imagined, the RAF had mixed feelings about the re-equipment plans foisted on to it by the incoming Labour government in 1965. The ambitious — some would say overambitious — aim of a frontline force of supersonic V/STOL P1154 strike/attack aircraft, backed up by the AW681 V/STOL tactical transport, would have given the RAF an unrivalled capability to operate from dispersed sites. The risk, though, was both technical and financial, and the new political incumbents felt that the RAF could have an acceptable capability based around less advanced 'off the shelf' designs. Both P1154 and AW681 were cancelled, the former requirement to be met by Phantoms, Jaguars and Harriers, while the transport needs were to be met by the C-130K Hercules. A few months later, the TSR2 programme was similarly terminated — though this time with a prototype actually in flight test — and the British aircraft industry was dealt a blow from which it has never recovered. But this, as they say, is another story.

The Harrier with which the RAF was to be equipped, though, was a very radical aircraft, and it was obvious from the outset that its operational use was going to require some new tactics, not to mention deployment methods. Also, despite the fact that the Harrier was subsonic (and thus lacking in sex appeal *vis-à-vis* the P1154), the production aircraft still represented a considerable design rework over the earlier P1127 and Kestrel. Underlining its operational ground attack role, the Harrier has five stores stations — two under each wing and one on the fuselage centreline, between the gun pods. The inner stations are plumbed for fuel tanks, and jettisonable 100gal (455l) or 330gal (1,500l) can be carried. An inertial nav/attack system was specified, in the form of the Ferranti FE541, with a Smiths Head-Up Display and a moving map display, to give the RAF the degree of accuracy in navigation it had specified in its Operational Requirement. Also fitted was a port oblique 70mm camera, to be supplemented (for the tactical reconnaissance role) by a centreline-mounted recce pod containing five further cameras. In short, the Harrier was an operational aircraft, born out of P1127 and Kestrel and sharing many of their features, but in fact very much a new design. The enlarged intakes to cater for the greater mass flow of the Pegasus 101 were but the most obvious external sign of this transformation.

The six DB Harriers, XV276-281, came off the Kingston line starting in summer 1966, and the last of these made its first flight on 14 July 1967. These were development aircraft pure and simple, and all were used either by the manufacturers, Boscombe Down or Rolls-Royce for initial proving, evaluation and service clearance to meet a tight timescale. None ever saw squadron service. Meanwhile, a production batch of 60 Harrier GR1s had been ordered, these being intended to form a training unit and an operational squadron at RAF Wittering and a second frontline squadron in RAF Germany. Viewed in retrospect, the Harrier development programme must be seen as aggressive (at least for a British aircraft) as it involved 12 development aircraft — the six DB Harriers and the first six production aircraft. Few changes were made between the DB aircraft and the first production Harriers, although one detail difference discernible on photographs resulted from the decision in the summer of 1966 again to change the intake design. This involved a slight increase in frontal area and the fitting of eight (rather than six) blow-in doors each

Below:
A Harrier GR3 of No 1417 Flight sits in its revetment at Belize International Airport. Standard weapons fit for the Flight's deterrence missions is two Aden 30mm gun pods, two 100gal drop-tanks and two 68mm Matra SNEB rocket pods. *Crown Copyright*

side. These changes, made necessary for the airframe to take advantage of the increased thrust of the Pegasus Mk 103 then under test, were made on the line only to the last DB Harrier XV281, but XV276 and XV277 were later modified to the same standard. At the same time as the increase in the number of blow-in doors, their design was simplified, this making it less likely that one might be removed as a result of engine surge or a birdstrike, leading to its ingestion into the engine.

XV738 was the first production GR1, and made its first flight on 28 December 1967, being delivered to Bristol for engine development with Rolls-Royce. By mid-1968, development flying was well under way with the DB aircraft and the first production Harriers, based at Dunsfold, Boscombe Down and Bristol. As well as getting CA release for the Harrier itself, the need was to clear the carriage of the intended underwing stores — drop tanks, bombs and the SNEB rocket pods. Development flying continued through 1968, and at the end of that year the first six production aircraft had flown.

This tempo of delivery allowed the formation of the Harrier Conversion Team at Wittering in January 1969. This unit was formed from a cadre of air and groundcrew who had worked with Hawker Siddeley personnel at Dunsfold to learn the Harrier in detail prior to its entry into service. Wittering in Northants (now Cambridgeshire) had already been chosen as the UK Harrier base, and the Harrier Conversion Unit (HCU) was officially formed there on 1 April 1969. Its first aircraft, XV746, was delivered to Wittering on 18 April, and others followed. The RAF's philosophy was initially to convert experienced Hunter ground attack pilots on to the Harrier, and to this end No 1(F) Squadron — flying Hunter FGA9s at West Raynham until June 1969 — was chosen to be the first frontline Harrier squadron. Having worked up on the Harrier, the HCU was ready to start its first conversion courses in July of that year. The fact that only experienced pilots were selected for the first few courses was inevitable, as there was at this time no Harrier simulator and no two-seat trainer to ease conversion to the new and radical type.

May 1969 witnessed an event which fixed the Harrier firmly in the British public's imagination, and emphasised the type's arrival into service. This was the *Daily Mail* Transatlantic Air Race, in which teams had to make the fastest crossing, east-west or vice versa, between the city centres of London and New York. It was obvious from the start that the best times would be achieved by service teams, and an intense rivalry developed between the Fleet Air Arm with their helicopter-Phantom/helicopter mode of transport and the RAF. A pair of Harriers, XV741 and XV744, were fitted with 100gal drop tanks, a fixed refuelling probe and bolt-on wingtips — all standard options for service Harriers. Although their cruising speeds would undoubtedly be slower than those of the Phantoms, and a number of in-flight refuellings would be needed, the Harriers proposed using their VTOL capabilities to the full by taking-off from the coal yard at St Pancras station in Central London. Recording an eastbound time of 5hr 31min, the Harrier underlined its flexibility of operations and basing; the importance of winning a prize in the race was secondary. As an aside, this fitting of the extended wingtips, intended to improve the cruise range, must have been the first and almost the last use of these bolt-on attachments; enquiries at Wittering in 1988 of both engineers and pilots could find nobody who had ever seen such devices, let alone flown with them!

Conversion of No 1 Squadron pilots started in July, under the wing of the HCU. The squadron's conversion was to be undertaken in two parts, with the initial intake comprising the eight pilots of 'A' Flight and Gp Capt P. G. K. Williamson, who had led the RAF team in the Transatlantic Air Race. Early sorties were flown from West Raynham, using the facilities vacated by the tripartite Kestrel unit, since Wittering's rebuild for the Harrier was not yet completed. After the first conventional sortie, the second for each pilot was a vertical take-off followed a few seconds later by a vertical landing. This was repeated a number of times, sortie length being increased for the pilot to get a 'feel' of the Harrier's flying characteristics in the hover, when the conventional control surfaces are ineffective and are supplemented by the reaction control system using high-pressure bleed air. With no two-seat trainer available, the Harrier pilot under instruction was well briefed before take-off, but during the flight had only radio contact with an instructor on the ground. Later sorties taught the translation between vertical and forward flight. Most of No 1's pilots completed the conversion course without any undue difficulty, but a small number failed to adapt to the Harrier's unique flying qualities.

The HCU ran pure conversion courses on to the Harrier, and pilots completing the course returned to their squadrons for operational conversion. In the case of No 1 Squadron, a grounding of the RAF's Harriers from October through December 1969 following a crash interrupted flying, and to maintain the momentum of the work-up the squadron deployed to Cyprus in March 1970. The good flying weather in the Mediterranean allowed the rapid build-up of hours, and both aircrew and groundcrew became more familiar with the new aircraft. The summer of 1970 saw the squadron starting to operate off-base, with individual aircraft flying from fields and open spaces in the immediate area of Wittering. This was followed by flight-strength deployments into disused airfields and to wooded operating sites in East Anglia,

Below:
The flight commander of No 1417 Flight is a squadron leader, and the other pilots are drawn from the frontline squadrons in RAF Germany. No 1 Squadron did rotate its pilots on the Belize duty, but this ceased at end-88 with the GR5 re-equipment. Seen here in the latter part of 1988 are the four pilots of No 1417 Flight in front of a GR3 adorned with the Flight's badge, which features a sailfish. They are, from left to right: Flt Lt Lance Nicol (3 Squadron); Sqn Ldr Les Garside-Beattie, OC No 1417 Flight; Flt Lt Paul Gunnell (3 Squadron); Flt Lt Ashley Stevenson (4 Squadron). *Crown Copyright*

giving the unit the chance to test out its newly-developed techniques of aircraft camouflage and dispersed site operations. For this type of deployment, not just the aircraft, pilots and groundcrew needed to move off-base and into the rudimentary conditions of the flying site; the whole squadron had to be prepared to pack and move out, and to live with the aircraft in the field. Finally, on 1 September — 14 months after the first pilots started conversion — No 1 Squadron was declared operational on the Harrier GR1, the first V/STOL jet fighter squadron in the world. Those looking for apposite statements noted with pleasure the squadron's motto *In omnibus princeps* — 'First in all things' — and pointed to the fact that No 1 had had a previous period of vertical flying, serving as a balloon squadron with the RFC in 1912.

The last of the six pure conversion courses run by the HCU finished in February 1971. On 1 October of the previous year, an expanded Operational Conversion Unit, No 233 OCU, had been formed at Wittering, utilising the HCU instructors and a number of new instructors. The new unit retained No 233 OCU's emblem of a Welsh wild cat, and the new design was painted on the nose of its Harriers. By the time of the formation of the OCU, the Harrier force was expanding, and there were pilots who already had experience (with No 1 Squadron) in the operational use of the aircraft, who could use this to assist the training effort and the formation of new squadrons. Four of the squadron's pilots were posted to No 4(AC) Squadron in June 1970, when RAF Germany's first Harrier squadron began its work-up, and squadron pilots began to be fed back into the OCU as instructors, to pass on their operational experience. The arrival of the first two-seat Harrier T2 at Wittering in July 1970 certainly facilitated pilot conversion, and the OCU courses (unlike those of the HCU) were expanded to include attack profiles, weapons delivery and use of the camera for the recce role.

While the RAF Harrier build-up continued, and further contracts were placed for 18 additional GR1s (one as a replacement for XV743, which had crashed within six weeks of its first flight while still with Hawker Siddeley) and 12 T2 two-seaters, US Marine Corps' interest in the Harrier had crystallised into a firm order. It is difficult, so long after the event, to know for certain whether or not the story of US Marine Corps pilots arriving at Hawker Siddeley's Farnborough chalet in 1968 and announcing that they wanted to fly the Harrier is apocryphal. Here, one's opinion should not be coloured by any personal experiences, which might suggest that at Farnborough 1988 they would undoubtedly have been refused entry to the chalet by a surly commissionaire. What is certain is that the initial visit to Farnborough by these two US Marine Corps officers led to their making initial assessment flights at Dunsfold, and to the arrival of a full evaluation team in January of the following year. The history of the US Marine Corps' use of the Harrier is outlined in a separate chapter, but there is no doubt that American service experience of the type has had a very significant effect upon the whole Harrier programme.

Top:
Air-air shot of GR1 of No 223 OCU/Harrier Operational Conversion Unit, a unit which has been training RAF (not to mention FAA and Spanish Navy) pilots for close on 20 years. *BAe 732095*

Below:
Harrier GR1 XV281 on the deck lift of HMS *Eagle*, with Buccaneer S2s and a Sea Vixen FAW2 of the ship's Air Group in the background. This is a DB aircraft, which never served with any RAF frontline unit. Although undated, this photograph is believed to have been taken in the summer of 1970, when two Boscombe Down Harriers conducted trials on the carrier. Note that the Harrier has acquired *Eagle's* 'E' tail code. *BAe HC8*

These follow-up RAF orders made possible the formation of three RAF Germany Harrier squadrons. The second, No 20(F) Squadron, started to receive its new aircraft at Wildenrath in the latter part of 1970, and was at full strength by the end of the year. It was followed by No 3(F) Squadron, again at Wildenrath, which took delivery of its GR1s in 1972. Thus, by the end of 1972, the RAF's Harrier force was at full strength, with No 233 OCU and No 1 Squadron at Wittering and Nos 3, 4 and 20 Squadrons with RAF Germany at Wildenrath. Whilst initial deliveries of the T2 had been made to the HCU/No 233 OCU for use in conversion training, by 1972 each squadron also had one on strength for dual checks. The initial establishment of these frontline squadrons was high by today's standards; as an example, No 1 Squadron had 18 GR1s when first formed on the Harrier; in its final years of operations, this strength would have been around a dozen aircraft, including a two-seater.

While the first 78 RAF Harrier GR1s had all received the Pegasus Mk 101, Rolls-Royce had been developing and proving versions of the engine with increased thrust. The Mk 102 offered an extra 1,500lb thrust over the Mk 101,

Above:
A photograph taken to mark the re-equipment of No 1 Squadron with the Harrier GR1 in 1970. The tail-to-tail aircraft line-up and arrangement of personnel is a virtual copy of the first No 1 Squadron line-up photograph taken at Clairmarais in July 1918 when the aircraft were SE5As, even to the dog in the right foreground. Seen in the front line centre (6th from left in the middle group) is Wg Cdr Ken Hayr, then OC No 1, today AM Sir Kenneth Hayr.
Crown Copyright, Wittering 0006/89

Below:
Since the Falklands conflict of 1982, the Harriers of No 1 Squadron have regularly embarked in Royal Navy carriers for exercises. A recent example was Exercise 'Purple Warrior' in November 1987, when six GR3s deployed to the exercise area aboard HMS *Ark Royal*.
Crown Copyright, Wittering 0002/89

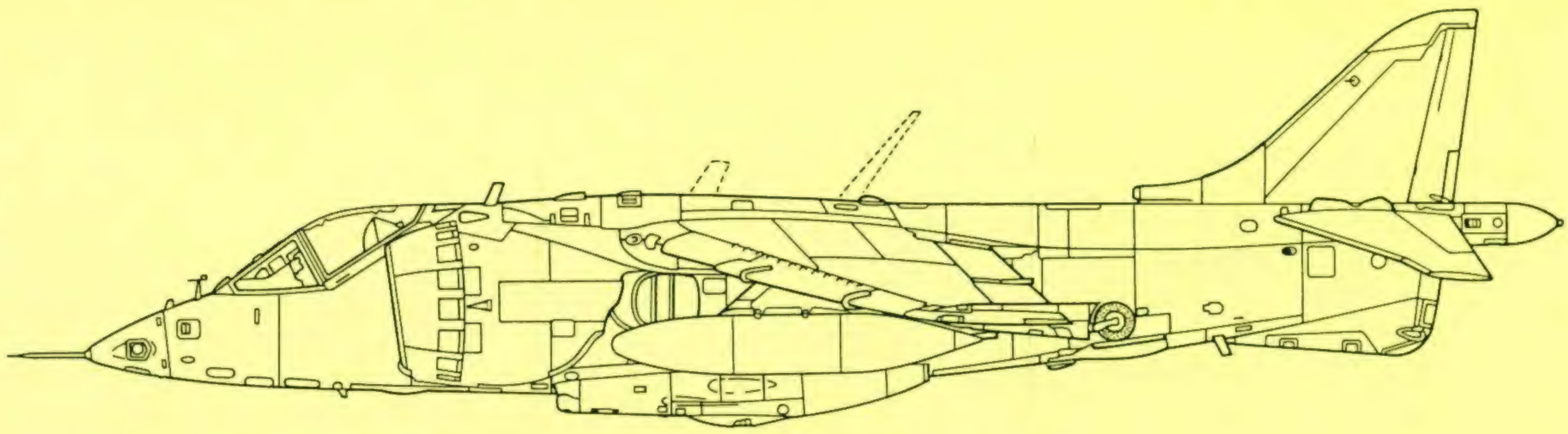
Above:
A line-up of GR1s of No 1 Squadron. The photograph is undated, but was probably taken in 1970/71. *Crown Copyright, Wittering 0005/89*

achieved by 'overspeeding'. The definitive version, the Mk 103, was also being developed, offering a further increase in thrust of 1,000lb as a result of a new fan and a number of other changes. These changes led to greatly improved handling characteristics, and this engine (or its close derivatives) has been the powerplant for all succeeding Harriers. Here, it should be noted that the thrust increase offered by both these versions over the 'baseline' Mk 101 was only at V/STOL ratings, and that no improvement is offered with the nozzles rotated aft for wingborne flight.

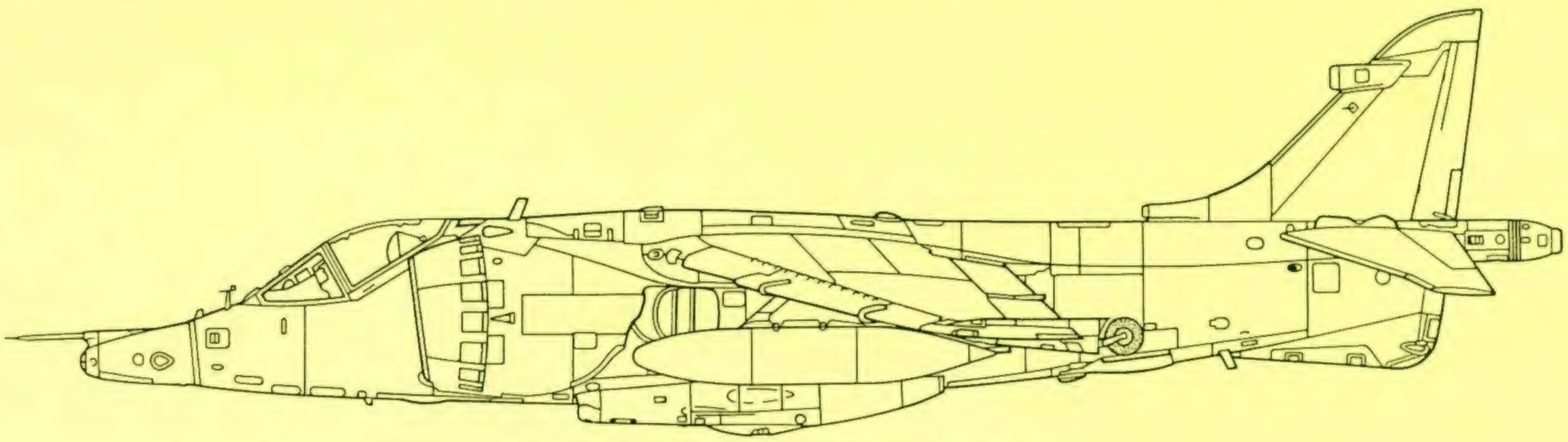
The RAF was at this point unwilling to invest heavily in a new engine, and all the aircraft in the first two batches of GR1 (60 and 18) were built with the Mk 101. This engine could, however, be reworked at the factory to Mk 102 or Mk 103 standard, and most of the GR1 fleet received Mk 102s in the early to middle-1970s. Thus equipped, the aircraft were designated GR1A; T2 similarly retrofitted became T2A. Initial deliveries of Mk 103-engined AV-8As were made to the US Marine Corps from 1971, but the first RAF single-seaters built from new with the engine were those in the 12 aircraft attrition batch ordered in 1974 and delivered from 1976. Fitted with the Mk 103, the single-seater was designated GR3. As well as the new-build aircraft, earlier GR1s and GR1As received this version of the Pegasus when the installed engine was due to be 'pulled' for major overhaul. Thus equipped, these single-seaters also received the GR3 designation, in the same way that Mk 103-engined two-seaters became T4. A total of 62 GR1/GR1A is believed to have been modified to GR3 standard.

In the light of operational experience, a number of changes were made to the RAF Harrier fleet in the early and mid-1970s. To improve reliability and to give improved electrical autonomy when operating in the field, RAF Harriers had their twin 4kVA alternators replaced by a new Lucas 12kVA system, as fitted to US Marine Corps aircraft on the production line. As part of the same programme, a Lucas Mk 2 gas turbine starter/APU with a 6kVA auxiliary generator was fitted to replace the earlier 1.5kVA unit. Despite being developed to RAF needs and funded by them, the first aircraft to be fitted were again US Marine Corps AV-8As, and RAF aircraft were retrofitted over a period. RAF Harriers do not make great use of the APU, but do use it to facilitate their pre-flight inertial alignment; more importantly, these electrical changes improve reliability and maintainability.

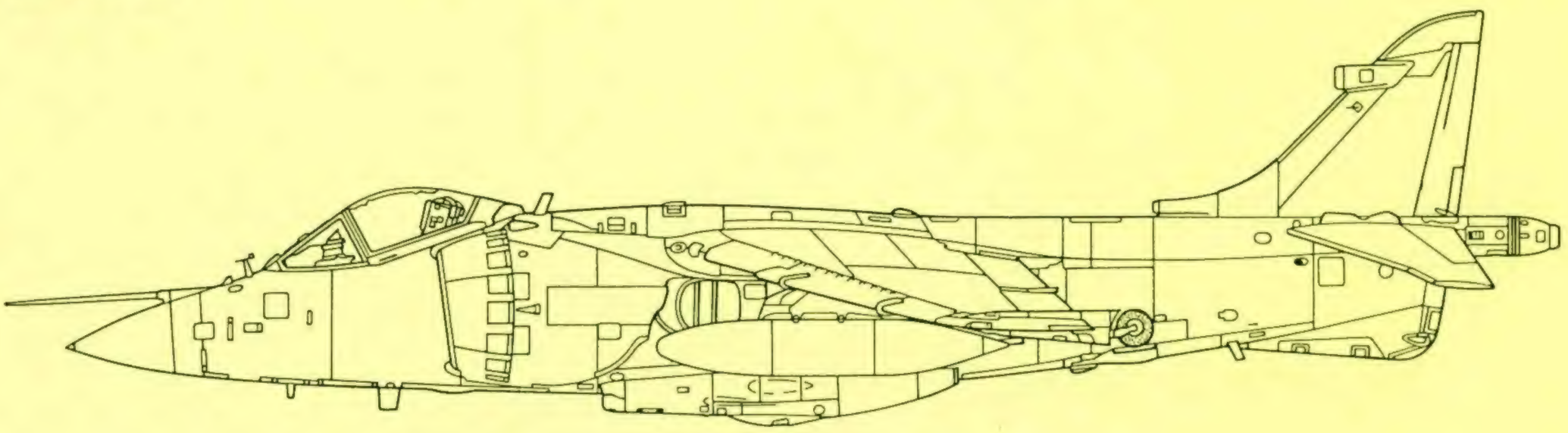
Almost certainly the most noticeable modification made to the GR3 concerns the fitting of the laser rangefinder in an extended 'Snoopy' nose and the Passive Warning Receiver (PWR) on the fin and rear fuselage. These were fitted in the 1970s as part of a major avionics update to the RAF fleet, and integrated with the FE541 system. Only made to the GR3 (and T4), these changes did not give rise to any new designation — reference to 'GR3A' in contemporary magazines to indicate single-seaters having received these modifications was thus unofficial. A Ferranti laser ranging and marked target seeking equipment (LRMTS) was fitted in an extended nosecone, this being closely related to the LRMTS fitted to RAF Jaguars. The equipment has the primary function of supplying laser-pulse derived range to the ground target, either along boresight or along a depressed or offset aiming mark provided by the FE541 system. It also has a search capability, seeking reflected IR radiation scattered by the target from an IR designator laser operated either by an airborne designator or by a ground-based operator. This equipment, first factory-fitted to the GR3 of the first 12 aircraft attrition batch, was subsequently retrofitted to all GR3s by 1979. Its employment has made drastic improvements in target acquisition and bomb delivery accuracy, especially in a single-pass laydown attack.



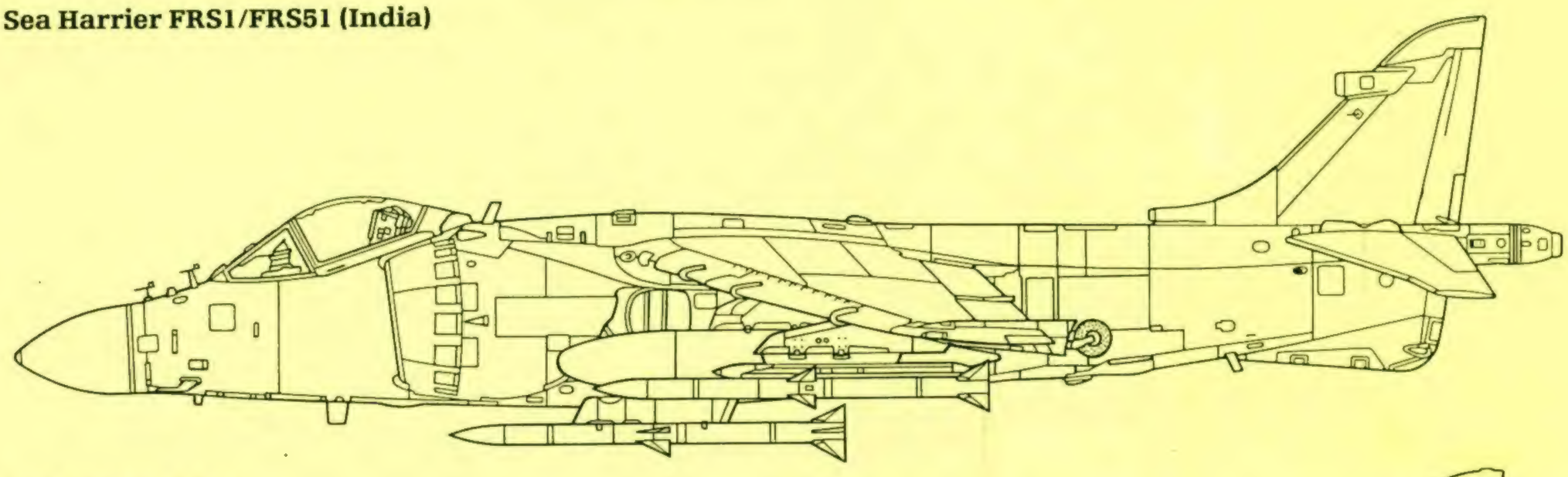
Harrier GR1/AV-8A (with large dotted aerial) AV-8S (with both dotted aerials)



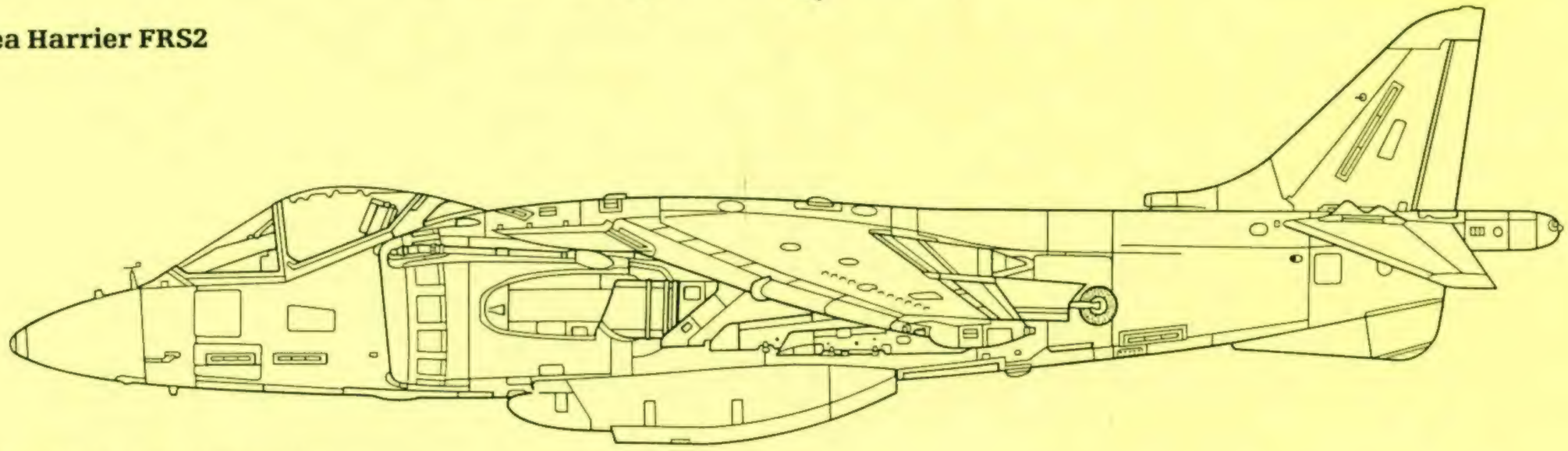
Harrier GR3



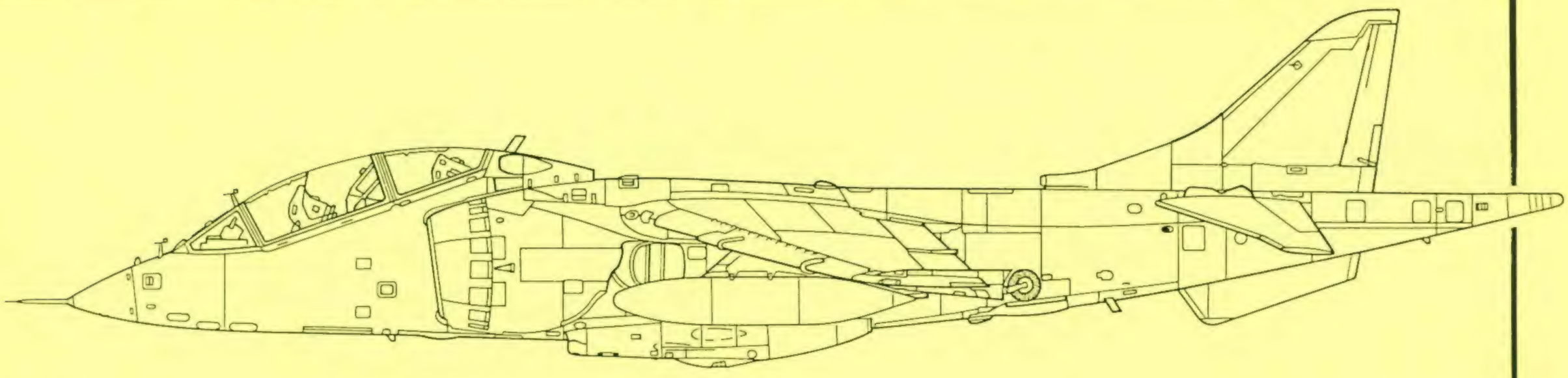
Sea Harrier FRS1/FRS51 (India)



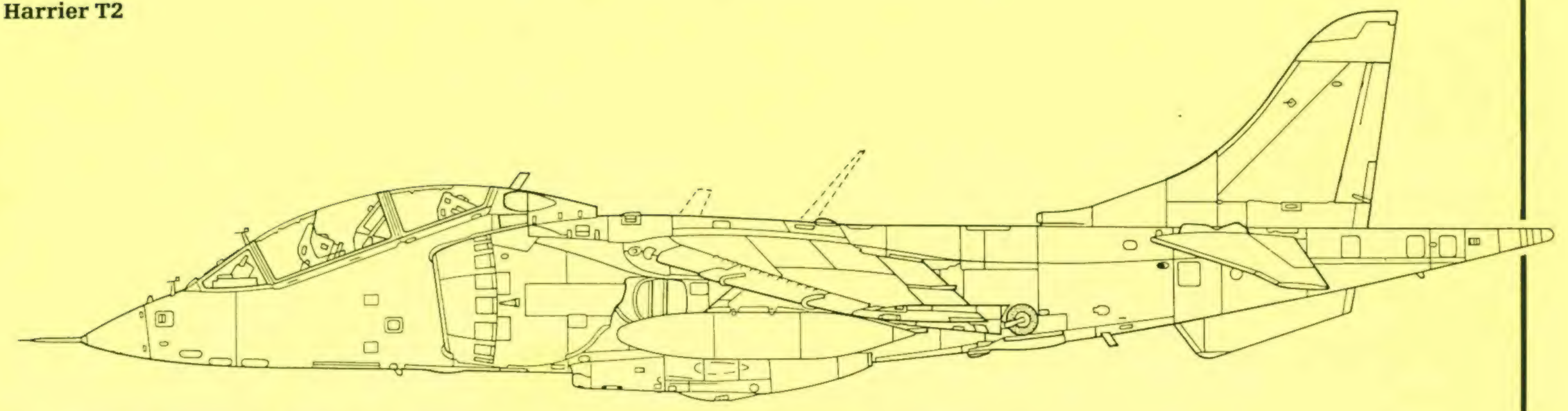
Sea Harrier FRS2



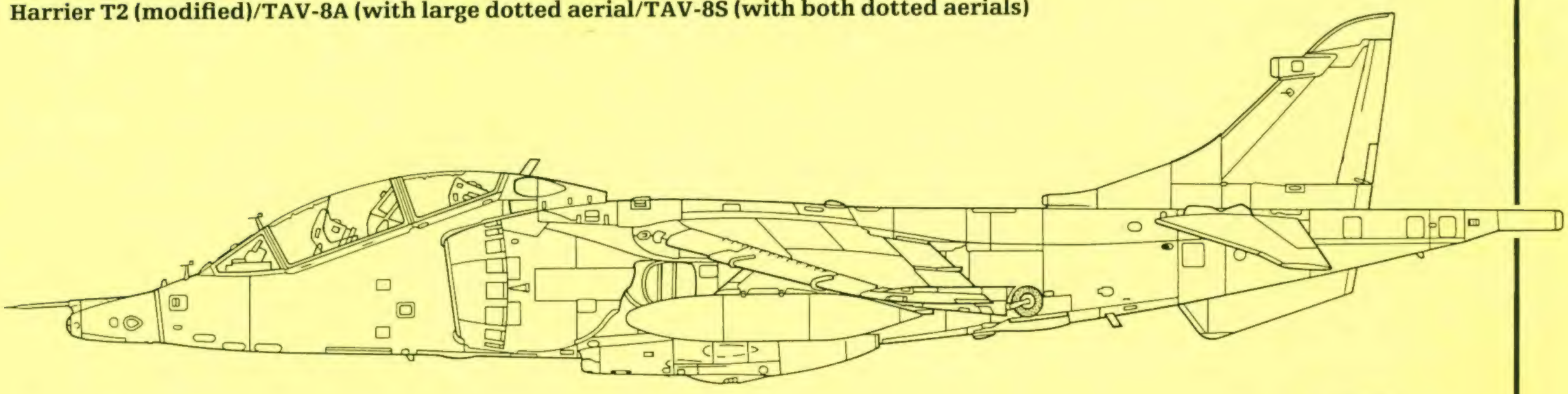
AV-8B EAV-8B Harrier II



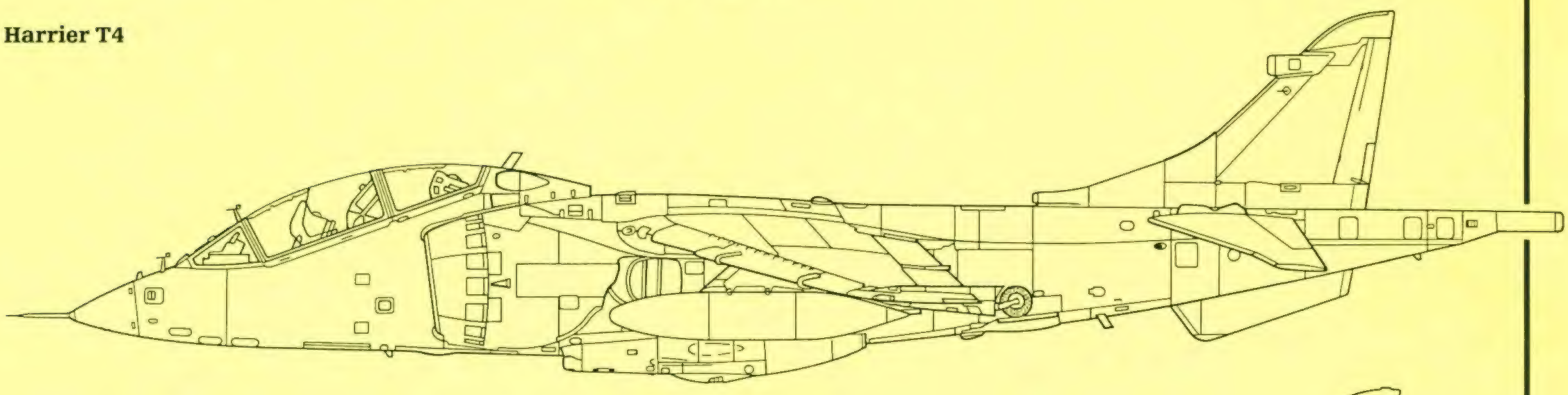
Harrier T2



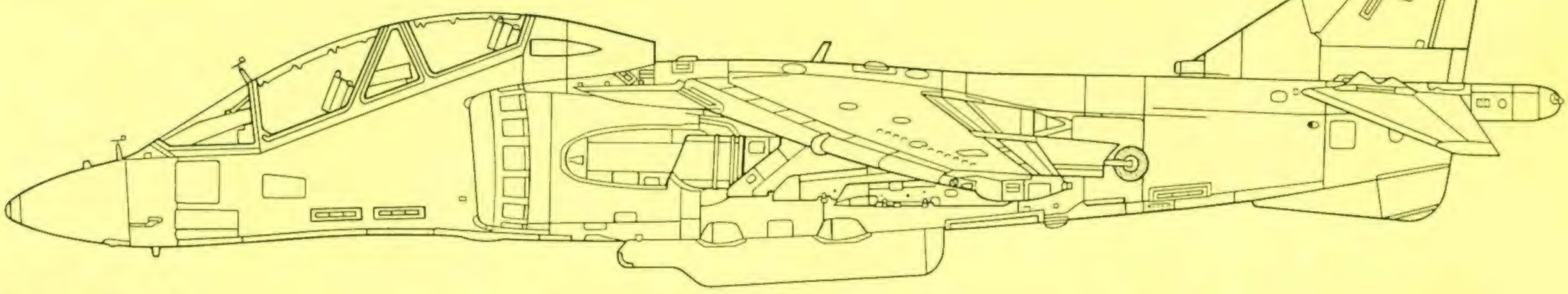
Harrier T2 (modified)/TAV-8A (with large dotted aerial/TAV-8S (with both dotted aerials)



Harrier T4



Harrier T4N/T60 (India)



TAV-8B Harrier II

Drawings by Mike Keep

Above:
GR1 XV794/K of No 4 Squadron is seen at the USAF base at Hahn on 10 June 1971. This aircraft was lost in a crash in Germany less than 12 months later. *Author*

As part of the same programme, a Passive Radar Warning Receiver (PWR) system was fitted, this involving the mounting of two antennae to the leading edge of the fin and the tailcone. Together, these provide a 360° coverage. To counteract the destabilising effect of the LRMTS, the fin was recontoured and enlarged to house the forward antenna, and flight testing proved that the net effect of these changes did not adversely affect handling. The PWR — an MSDS ARI.18223 — processes incoming signals (from radars illuminating the Harrier as a target), presenting directional information and analysing the radar's type and strength of signal as well as aurally alerting the pilot to the threat. It is up to the pilot himself, armed with this information, to decide on avoiding action. As-built, the Harrier did not have any chaff/flare capability, but a number of GR3s modified for the Falklands have had the Tracor ALE-40 chaff and flare dispenser fitted in the lower rear fuselage, while Phimat chaff dispensers can be fitted under-wing.

With the Harrier force at full four-squadron strength in the mid-1970s, the force regularly practised and refined its off-base deployment capability. Despite this clear indication that the Harrier offered the only practical aircraft able to operate without the luxury of runways — and a practical demonstration offered by the breakfast-time pre-emptive Israeli strikes on Egyptian air bases in the 'Six Day War' of 1967, which effectively removed the Egyptian Air Force's ability to operate — the Harrier found no new customers save the Spanish Navy. While the RAF Germany squadrons were receiving high marks in TACEVALs and showing that they could operate efficiently off-base even in NBC conditions, other NATO nations continued to look the other way when it came to ordering new attack aircraft. Even the RAF continued with Jaguar purchases throughout the 1970s, such that in 1977 one of the RAF Germany Harrier squadrons — No 20 — was re-equipped with the Jaguar GR1. This move, though, was achieved at no reduction in frontline Harrier strength in RAF Germany, and came about for administrative and logistical reasons. The decision had been taken to move the Harrier force from Wildenrath, one of the 'Clutch' bases on the Dutch border near Venlo, to Gütersloh, the nearest RAF Germany base to the East German border. At this time, it was decided to merge the three squadrons, each then having two flights and a strength of around 12 aircraft, into two new 'large' squadrons of three flights and 18 aircraft. The 'surviving' squadrons were Nos 3 and 4, and No 20 was the one chosen to re-equip with the Jaguar. This move was thus a logical one, but — at least on paper — one is left with the impression that even the RAF was replacing Harriers with CTOL types!

The situation with regard to the RAF Harrier squadrons is basically unchanged today, although re-equipment with the GR5 is now underway. Both the role and the geographical operating area for the RAF Germany squadrons is clearly defined, and is highly unlikely to be altered by any political or military policy changes. A more detailed discussion of the off-base operations of these squadrons is given in a separate chapter in this book.

No 1 Squadron, on the other hand, has a much more flexible role. Based in the UK at Wittering it has, from its formation, exercised the capability to deploy and operate from anywhere. Assigned originally to the Allied Command Europe (ACE) Mobile Force (but now to SACEUR Strategic Reserve), its role has been to be ready to deploy to either the Northern or Southern flanks of NATO in times of international tension or war. This capability was practised regularly in the 1970s on both flanks, but in recent years exercise deployments to the Southern (Greece/Turkey) operating area seem to have ceased. Annual exercises, though, have been made to Northern Norway in the early part of the year, with the squadron's Harriers spending several weeks operating in the sub-zero temperatures north of the Arctic Circle. As early as September 1970, a matter of weeks after the squadron had been declared operational, the CO led six aircraft to the Norwegian airfield at Bardufoss, where they exercised with the ACE Mobile Force ground troops. These Norwegian deployments — normally to either Bardufoss or Tromso — have generally taken place annually, although in recent years only once every two years have they been at squadron strength. The most recent such deployment was Exercise 'Snow Falcon' in early February 1988, when four GR3 and a T4 of No 1 Squadron went to Bardufoss. In view of the recent re-equipment of No 1 Squadron with the GR5, there will probably be no such Harrier presence in the 1989 exercises in Norway. Operating on the northern flank — from Norway, Denmark or even Northern Germany — the Harriers of No 1 Squadron would in wartime need the capability to attack invasion vessels, fast patrol boats etc, as well as army formations. For this reason, the squadron keeps the 68mm SNEB rocket pod as an armament option, alongside the BL755 cluster bomb and laser-guided weapons.

In line with the RAF's policy of No 1 Squadron being ready to deploy as required, the unit has on a number of occasions detached aircraft to fly from British aircraft carriers. The first such occasion was in the summer of 1971, when four aircraft flew from HMS *Ark Royal* off Rosyth, to be followed by a short period aboard for three aircraft in July 1973. Regular deployments were

made to Cyprus for APC, and their first transatlantic flight was made in summer 1972 when two aircraft made a nonstop, Victor-refuelled crossing to take part in the Toronto air show.

The need to undertake a rapid deployment came for real in October 1975, when the squadron was given one week's notice of the need to deploy six aircraft to Belize. This small country, previously the colony of British Honduras, was being threatened with invasion by neighbouring Guatemala, and the Harrier was chosen as the ideal aircraft to operate from the primitive conditions at Belize Airport. The six aircraft staged nonstop across the Atlantic, then south through America to arrive at Belize, where they immediately started to fly to make their presence known to those on the other side of the border. Their timely appearance on the scene may well have prevented an invasion, but it has not proved as easy to extricate British forces from Belize: in 1989, a RAF Harrier detachment is still in place, and has acquired its own identity as No 1417 Flight.

If ever there was a requirement for an 'out of area' deployment for the RAF Harrier force, it was the need to join the British Task Force in the South Atlantic in 1982, in 'Operation Corporate' following the Argentinian invasion of the Falkland Islands. No 1 Squadron was put on alert on 10 April 1982, to be used as a reinforcement for the Sea Harriers embarked in HMS *Hermes* and *Invincible* in case of high attrition of Sea Harriers. Although No 1 was the squadron chosen actually to deploy, the RAF Germany squadrons were told to be prepared to release aircraft and possibly pilots for the operation. Aircraft strength on the squadron was 14 GR3s and one T4, but a further eight GR3s were drafted in from the OCU and No 4 Squadron. From these, 16 aircraft with a good number of hours before the next major overhaul were selected, and were prepared for maritime operations.

In view of the need for the GR3 to operate from a carrier deck and in an interceptor role, a number of modifications were planned and rapidly executed. Shackles were added to the outriggers to allow the aircraft to be tied down to a carrier deck and an I-band transponder (as used on FAA Sea Harriers) added under the nose, this to facilitate carrier approaches. Ferranti quickly developed a trolley-mounted FINRAE (Ferranti Inertial Rapid Alignment Equipment) to allow the alignment of the GR3's INS on a rolling ship's deck. Perhaps even more impressive was the fitting of the necessary wiring and switches to allow the GR3 to mount a pair of AIM-9G Sidewinder AAM on the outer pylons. The provision of AAM capability, which the RAF had requested for more than 10 years, took less than a month from initial design through A&AEE acceptance and trial Sidewinder firing at Aberporth. Purchased in the States, ALE-40 chaff/flare dispensers were fitted to 10 Harriers to improve their self-defence; the other aircraft sent to the South Atlantic had only the possibility of a 'one-shot' load of chaff packed into the airbrake fairing. Together, these updates were known as the 'Corporate Mods', and represented as large an improvement in GR3 capability as had ever been seen on the fleet, apart from the earlier fitment of LRMTS and PWR.

As the Wittering pilots had little experience of a primary air-air role, they started in earnest flying DACT (Dissimilar Air Combat Training) with RAF Lightnings, while the French Armée de l'Air generously detached a Mirage III to Coningsby to give them a chance to fly against a likely Argentinian adversary type. Ski-jump training was given at RNAS Yeovilton in mid-April, this apparently posing no problems to the RAF pilots. Ten of the modified Harriers flew nonstop to Ascension Island, in flights of three or four, refuelled by Strike Command Victor tankers, between 2 and 6 May. Of these, six were transported to the Falklands as deck cargo in the container ship *Atlantic Conveyor*, hastily converted as a Harrier carrier with a take-off pad. After 12 days at sea, these aircraft transferred to HMS *Hermes*, joining the Sea Harriers of 800 Squad-

Below:
This nose of a GR1 of No 3 Squadron, sporting the squadron badge which features a cockatrice, was photographed at the RAF Tactical Fighter Meet at Leuchars in August 1976. At this time, the RAF's frontline Harrier fleet was an evolving mix of GR1/1As and LRMTS-equipped GR3s. *Author*

'Operation Corporate' – Harrier force deployment
(Courtesy BAe Kingston)

TRANSIT METHOD	RN Sea Harriers	RAF Harrier GR3s
EMBARKED IN UK:		
HMS Hermes	12	—
HMS Invincible	8	—
FLOWN* UK TO ASCENSION IS. then		
★ via Atlantic Conveyor to 52°S. (Flown off to VL on carriers.)	8	6
★ via Contender Bezant to 52°S. (Flown off direct to Port Stanley)	—	4
FLOWN* UK TO LAT. 52°S with intermediate landing at Ascension Is. VL on HMS Hermes	—	4
TOTALS	**28**	**14**

*Refuelled in flight using RAF Victor tankers

UK - Ascension Is. ≏ 3700n.m. (6850 km)
Ascension Is. - Falkland Is. ≏ 3250n.m. (6050 km)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Left:
GR1 XW630/U of No 3 Squadron, photographed at Wildenrath on 28 February 1977, the last day of No 3's Harrier operations before re-equipping with the Jaguar. *Jürgen Valley*

Below left:
A GR3 of No 4 Squadron gets airborne from a stretch of road which serves as the runway at Site 4 'Eberhard' in May 1988. *Author*

Above right:
T4 XW270/T of No 4 Squadron is glimpsed inside its hide between sorties from 'Eberhard', a flying site used for exercises in the Sennelager Training Area, May 1988. *Author*

Right:
XZ971/G of No 1417 Flight is pictured over the Caribbean on a sortie from Belize International Airport in 1988. *Jon Lake*

Below:
The scene at Tromso Airport in northern Norway in March 1982, to which 12 RAF Harrier GR3s of No 1 Squadron had been detached for Exercise 'Anorak Express'. GR3 XZ129/29 in Arctic white (water-soluble)/ green camouflage taxies out for a sortie. *Author*

ron aboard. Further GR3s followed this initial group out from Wittering, and a total of 10 Harriers was available in the theatre before the ceasefire of 14 June. Embarked in *Hermes*, the GR3s began an intensive work-up for their intended interception role. In fact, Sea Harrier attrition was lower than had been feared, and after the first couple of days the operational use of the GR3 was exclusively for ground attack or low-level recce sorties.

During the weeks up to the Argentinian surrender, the GR3 flew 150 sorties, most of them operational and the majority from on board *Hermes*, but some from the rudimentary Forward Operating Base (FOB) at San Carlos. Many ground attack missions were flown against aircraft and helicopters on the Falklands, and to try to render unusable the runway at Port Stanley. CBU (Cluster Bomb Unit), 1,000lb bombs and FAA 2in rocket pods were the standard armament used on these missions, but the bombs' accuracy left something to be desired at the low release heights which were necessary. An early attempt to use the GR3's LRMTS to designate for Sea Harriers carrying Paveway LGBs (Laser Guided Bombs) was not successful, but later GR3 attacks with LGBs where ground-based laser designators were used gave more satisfactory results. Three GR3s were lost in this time, plus a fourth which was damaged and later assessed as Cat 5 (a write-off).

The No 1 Squadron detachment put ashore to establish a land base at Port Stanley — or RAF Stanley as it had become — on 4 July, at which time it adopted the title of Harrier Detachment or 'Har Det'. This followed a period in which the GR3 has maintained a Combat Air Patrol or flightdeck alert on-board *Hermes* immediately after the ceasefire, should the Task Force again come under attack. At RAF Stanley, AIM-9G-armed Harriers held a similar air defence alert, initially with pilots in cockpit but later eased to a 5min readiness.

The pilots of No 1 Squadron, battle weary, were soon returned to the UK, to be replaced in Har Det by pilots from RAF Germany squadrons, although the Harriers remained at RAF Stanley for nearly three years. Har Det was officially renamed No 1453 Flight in August 1983, and remained in being to provide air defence for the Islands until May 1985 and the opening of RAF Mount Pleasant. During this time, personnel were supplied on a rotational basis by all three of the RAF Harrier squadrons. The stationing of air defence Phantoms at RAF Mount Pleasant finally removed the need for the Harriers, and they were returned to the UK.

Operation 'Corporate' almost certainly provided the first and last occasion on which RAF Harrier GR3 flew operational missions, although the aircraft of No 1417 Flight continue to keep the peace in a volatile situation in Belize, and as recently as 25 November 1988 were called upon to give a show of force to a Guatemalan gunboat. No 1 Squadron, meanwhile, continues to deploy aboard Royal Navy carriers. In Exercise 'Purple Warrior' in November 1987, six GR3s were deployed to the 'combat zone' (Galloway, SW Scotland) aboard HMS *Ark Royal*, flying CAP alongside the Air Group's embarked Sea Harriers. To make good the attrition in the Falklands, four additional GR3s (with 'ZD' serials) were ordered. These aircraft, today by far the lowest-houred in the RAF fleet, bring to total GR3 buy to 118. The RAF GR3 in Strike Command and RAF Germany squadron service will largely have been replaced by the GR5 by 1990, to the point where no more major overhauls are being carried out. It thus seems likely that these final 'new' GR3s will, over the next year or so, be brought together on to the strength of No 1417 Flight at Belize, as the last operational GR3 user.

Above:
Two Harrier GR3s of No 1 Squadron are pictured operating from the Norwegian civil airport at Tromso in Exercise 'Anorak Express' in March 1982, just a few weeks before the Falklands conflict. The aircraft deployed to Tromso — nine GR3s and a T4 — were all painted with a water-soluble white paint, this covering the normally grey areas of the camouflage. *Author*

Below:
Five Harrier GR1s of No 1 Squadron are pictured on the squadron flight line at Wittering on 5 December 1973. *M. Horseman*

USMC AV-8A Service

Above:
Early US Marine Corps AV-8A deliveries were made by air using USAF C-133 Cargomasters. This photograph, although undated, shows the second US Marine Corps AV-8A 158385 taxying past a C-133 at Dunsfold, while another Harrier (presumably 158384) is being loaded into the hold. This would date the photograph at January 1971. *BAe*

The US Marine Corps evaluation team which visited the UK in early 1969 returned home with good reports of the Harrier, an aircraft whose operational concept appeared ideally suited to the Marines' requirements. With 'support of the Marine on the ground' being the cornerstone of the US Marine Corps' philosophy, the Harrier's ability to fly CAS missions from ships, unimproved sites or beachheads was without equal. Marine Corps plans to acquire 114 Harriers were formulated, these to be ordered in batches between Fiscal Years 1970 and 1975. But from the start, the AV-8A (the Harrier's US designation — 'Attack' and 'VTOL') programme was a political hot potato. There were many reasons for this, and the fact that the Harrier was subsonic and with a relatively restricted payload/range was probably just as important as the argument that the type was 'not invented here'. To counteract this latter objection, HSA signed in 1969 a licence agreement with McDonnell Douglas giving the St Louis-based company the exclusive rights to market and manufacture the Harrier and its derivatives in the States, and agreeing collaboration on future Harrier and V/STOL aircraft developments. In 1971, Rolls-Royce similarly signed a deal with Pratt & Whitney, to cover development of the Pegasus (US military designation F402) and the rights for licence production.

In retrospect, both these agreements have been beneficial to the British companies involved, and to the Harrier as an aircraft. Because of the way in which AV-8A batches were ordered, year by year, it never proved worthwhile starting production of the aircraft in St Louis, and Pegasus engines likewise continued to be built in the UK. Production of the AV-8A was at Kingston, with final assembly at nearby Dunsfold. After test flying, the aircraft were disassembled (wings off) and delivered to the USA in USAF C-133 transports direct from Dunsfold. When the C-133 was retired from service, the AV-8s were transported by road to RAF Mildenhall, there to be loaded into MAC C-141s. Final production of the AV-8 was 110 aircraft, with the last (fifth) batch of 24 aircraft being reduced to only 20, comprising eight two-seat TAV-8A and 12 AV-8A, reflecting the higher cost of the two-seater. The fact that the TAV-8A was only made available to the US Marine Corps in the final production batch, and from late 1975, meant that the trainer had little impact on the AV-8A's service introduction. Its eventual availability did, however, have a beneficial effect on the AV-8A's accident rate.

The uprated Mk 103 engine was specified for the AV-8A, but in fact the first 10 aircraft had the interim Mk 102 when deliveries started in January 1971, and were retrofitted later. Much of the equipment fit specified for the AV-8A was the same as for the RAF GR1, the majority of differences being the result of the Marines' need to carry standard US weapons. From the start, the AV-8A was made compatible with the AIM-9 Sidewinder, the appropriate wiring being incorporated to the outer wing pylons, this reflecting the Marines' secondary requirement for air superiority. Since the AIM-9 was not at that time cleared for RAF use on the Harrier, contractor flight testing was carried out in the UK. The 30mm Aden cannon were, surprisingly, retained. Although early AV-8As had the FE541 nav/attack system fitted, this proved to be an overkill for the Marines' use of the aircraft, and the equipment was deleted as from production aircraft No 60, and subsequently removed from those already in service. In its place, a simpler Smiths I/WAC (interface/

Above:
Sea Harrier FRS1 XZ495/003 of 801 Squadron, prepares to take off from the flightdeck of HMS *Invincible* on 1 June 1981. *Author*

Left:
Viewed from the plane guard Sea King, Sea Harrier FRS1 XZ495/003 positions for a ski-jump take-off from HMS *Invincible* in June 1981. *Author*

Above right:
VMA-513 AV-8As on alert at the Marine Corps Air-Ground Combat Center (Twenty-nine Palms, California) Expeditionary Airfield during a combined arms exercise in January 1981. *Frank B. Mormillo*

Right:
TAV-8A 159378 (the first of eight for the US Marine Corps) of VMAT-203 is seen on the flightline at MCAS Cherry Point in August 1985, with the pilots climbing out of the cockpit after a conversion sortie. *Author*

Right:
EAV-8B 01-904 of *Escuadrilla 009*, prepares for a vertical take-off from the deck of *Dedalo*, in Rota harbour on 17 October 1988. *Author*


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weapon aiming computer) was introduced, which carried out the necessary weapons aiming calculations and presented the information using the HUD symbology.

Far more limited in capability than FE541, this fit was known as the Baseline system and it met the Marines' needs with a reduction in complexity and maintenance requirements. A final change, introduced from the 90th AV-8A, was the fitting of an American ejection seat, the Stencel SIIIS-3, in place of the Martin-Baker Type 9 Mk 1. This change was part of a broad US plan to produce a Stencel seat for use in a number of US Navy aircraft types. Whilst the Stencel seat was slightly lighter than its British equivalent, and pilots found strapping-in somewhat quicker, in the most important parameter — effectiveness in use — the success rate has been about the same with both seats.

Operationally, the US Marine Corps formed three frontline squadrons of 20 aircraft each (later reduced to 15 by attrition) with VMA-231 'Ace of Spades' and VMA-542 'Flying Tigers' as part of MAG-32 at Cherry Point, North Carolina and VMA-513 'Flying Nightmares' at Yuma, Arizona. All conversion on to the Harrier was carried out by VMAT-203 at Cherry Point, which had both AV-8A and all the service's eight TAV-8A two-seaters on strength. The training task for VMAT-203 was at a high level of intensity in the early and mid-1970s as the frontline AV-8A force built up, but then stabilised with a requirement for around 15 new pilots a year.

From the beginning, the US Marine Corps had the intention to operate the AV-8A from ships as well as from airfields and dispersed sites. The AV-8A's BIS (Board of Inspection and Survey) acceptance trials at Patuxent River, Maryland in early 1971 included operations from the USS *Guadalcanal* and USS *Coronado* — the former an amphibious assault carrier, the latter a smaller vessel with a rear landing platform only. As a result, the AV-8A was cleared for operations from both LPH and LPD, the first jet aircraft to receive such approval. At the time, RAF Harriers had only operated from the larger Royal Navy attack carriers. Early flying at Patuxent River, especially by Maj Harry Blot, also led to the first official investigation of VIFFing (Vectoring In Forward Flight) — making use of the Harrier's rotating engine nozzles in wingborne flight to achieve sudden changes of attitude or position in combat. With only minor engine modifications, the AV-8A (and RAF Harrier) was given service clearance for use of

Top:
AV-8A 159370 CG-5 of VMA-231 photographed in April 1977. It is believed this was an aircraft of Detachment A, at Kadena. *L. B. Sides collection*

Above:
158384 was delivered to VMA-513, but later became the prototype AV-8C. It is seen here, with a camouflage scheme brightened by areas of dayglo, at the McDonnell Douglas plant at St Louis on 28 July 1978, when it was involved in AV-8C development. *Author*

Top:
An AV-8A gets airborne from the deck of USS *Guam* (LPH-9), probably in January 1972, when VMA-513 embarked in *Guam* for operations in the North Atlantic to test the feasibility of joint Harrier/helicopter operations under the 'Sea Control Ship' concept. *BAe 723311*

Above:
AV-8A Harrier 158965 of VMA-513 demonstrates its vertical landing capability at an air show at MCAS El Toro in May 1978. *Frank B. Mormillo*

VIFFing. This did not make the Harrier into a dogfighter, but did give it a much better possibility of getting out of trouble when attacked, and the type's 'square turn' is still impressive.

US Marine Corps squadron operations of AV-8A (TAV-8A was deck qualified in trials aboard USS *Franklin D. Roosevelt* (CV42) in 1976, but has not been so used since) provided the majority of the input on deck operations of the Harrier, at least until the entry into FAA service of the Sea Harrier. Sorties by VMA-513 AV-8A aboard USS *Guam* in the North Atlantic in 1973 saw flying operations in weather conditions which grounded the embarked helicopters. In 1975, six AV-8As of the same unit undertook a six-month cruise in the Mediterranean aboard USS *Guam*, while June 1976-April 1977 saw the first squadron strength AV-8A deployment aboard a US Navy attack carrier (CV), on USS *Franklin D. Roosevelt*. This historic cruise, which took the carrier to the Mediterranean, involved CVW-19 and its component F-4, A-7, E-1B and helicopter squadrons. What was different for this deployment was the addition of 14 AV-8A of VMA-231, the first time the AV-8A had been integrated into the cyclic operations of a CV. To employ the AV-8A within the standard 1.5hr flight periods for CTOL aircraft, the Harriers generally took-off last and recovered first. The AV-8A used only the axial deck area, employing both rolling and vertical take-offs. For recovery, standard jet landing approaches were flown until the AV-8A was aft of the ship; at that point, the aircraft flew along the port side of the carrier, to land vertically just aft of the jet blast deflectors. The AV-8A on one

Above:
01-806, an AV-8A of *Escuadrilla 008*, comes in for a vertical landing on the pad at its Rota home base in October 1988. *Author*

Below:
Five Sea Harrier FRS1s of 800 Squadron, photographed in 1985 and carrying the 'Ł' tail code of HMS *Illustrious*. *BAe 853035*

Above:
A Sea Harrier FRS1 intercepts a Soviet Tupolev TU16 'Badger'. The photograph is undated, but it is believed to have been taken in the autumn of 1987 over the North Sea, from a second Sea Harrier using its F95 nose oblique camera. *Crown Copyright*

Below:
The new equipment of No 233 OCU (and indeed of the RAF's frontline Harrier squadrons) and the old — GR5 ZD324/B flies with a GR3, both carrying the Welsh wildcat OCU badge.
Crown Copyright

occasion demonstrated its ability to land when the wind-over-the-deck (WOD) was a 15kt tailwind — the aircraft simply made their landing approaches from the bow, and landed into the wind. Even while *Roosevelt* was anchored in port, the AV-8A continued flight operations. More than 2,000 sorties were flown on the cruise with no aircrew or aircraft losses, and proved conclusively the practicality of such operations. US Marine Corps AV-8A have since deployed frequently aboard US Navy ships, despite the fact that no vessels have been permanently assigned to operate or transport them, and squadron integration into a CVW is still the exception rather than the rule. Squadron detachments to Kadena, Okinawa were made in 1975 and 1976 by VMA-513. The need to deploy at squadron strength to overseas operating bases can be met either by air-air refuelling from US Marine Corps KC-130 or SAC KC-135 or KC-10 tankers, or at a slower pace aboard US Navy ships.

Over the years, attrition has been relatively heavy, with almost half the total buy being written off. In 1979, the decision was taken to rework 60 surviving AV-8As to an improved standard, to remain in service until the arrival of the AV-8B in around 1985. Starting point for this was a complete airframe overhaul under a Service Life Extension Program (SLEP), at which time new Lift Improvement Devices (LID) were fitted, these being a spin-off from the AV-8B development. Two large longitudinal strakes were fitted to the underside of the fuselage (or smaller strakes mounted on the Aden gun pods), with a retractable ventral dam at the front of these strakes and between them. These relatively minor modifications made a major improvement in V/STOL performance. RWR equipment was added in the tailcone, ALE-39 chaff/flare dispenser in the rear fuselage and an on-board oxygen generating system (the attractively-named OBOGS). An obvious external change was the addition of formation flying lights, while the F95 camera in the nose was deleted. The prototype for the conversion was 158384, which was tested at Patuxent River in 1979, and following this a total of 47 aircraft (as opposed to the 60 planned) received the modifications, the work being carried out latterly at Cherry Point.

Marine Corps use of the AVC-8A/C continued until August 1986, by which time the AV-8B had completely replaced the earlier mark. With the TAV-8B not at this time being available, VMAT-203 continued to use the TAV-8A for a further 18 months in the training and conversion programme, although this aircraft was less than representative of the flying characteristics of the AV-8B. No serious proposals seem ever to have been made to issue the AV-8A/C to the US Marine Corps reserve squadrons, despite the fact that this is a newer aircraft than many types which remain in the inventory. One can only assume that the AV-8A's flying characteristics were considered too demanding for the part-time reserve pilots. As a result, the remaining AV-8A/C and TAV-8A are now stored at AMARC Davis Monthan, with 43 present in early 1988 carrying park codes 7A001 through 7A043. None is likely ever to fly again, although it is believed that the Spanish Navy has purchased two for spares recovery, to support the continuing operation of their AV-8A fleet.

Below:
A line-up of three VMAT-203 Harriers at MCAS Cherry Point on 20 October 1982, when US Marine Corps AV-8A/C operations were still at the full three frontline squadron strength. *Peter Guiver*

Bottom:
VMA-542 was the last of the Cherry Point squadrons flying the AV-8A/C. The aircraft seen here on 21 August 1985 is AV-8C 158977 WH-05, and shows some of the mods which distinguish the rebuilt aircraft from the earlier AV-8A – formation flying lights, radar warning receiver antenna on the wingtips, triple-ejector racks and the deletion of the nose oblique camera. *Author*

Two-seat Harriers

When the Harrier GR1 first entered squadron service in 1970, there was no two-seater to aid conversion to the type. New pilots had extensive pre-briefings before vertical sorties, but flew them solo with only radio contact with the instructor on the ground; for conventional flights, the instructor had the option of flying chase in a Hunter. In an ideal world, there would have been a Harrier T2 available in the same timescale as the GR1, but the non-availability of the two-seater only mirrored the RAF's experience with the Lightning's service introduction 10 years earlier. In fact, a two-seat P1127(RAF) had been studied in parallel with the single-seater, but design office and production priority had been given to the aircraft which was to become the GR1. Drawing issue for the two-seater commenced in 1967, and the first prototype XW174 flew on 24 April 1969.

The RAF's operational requirement was primarily for a two-seat conversion trainer, but the service also wanted an aircraft which could fly operational sorties alongside the GR1. To this end, the T2 (as it was to become) was to be fitted with the same stores stations, the same nav/attack system and the same F95 camera in the nose as the single-seater.

The challenge in designing a two-seat version of the Harrier was in many ways greater than that normally experienced with a CTOL fighter. For a V/STOL fighter, changes to the centre of gravity caused by the installation of a second cockpit must be kept within the bounds imposed by the centre of thrust. In the case of the Harrier, there was no possibility of adopting the two-seat side-by-side layout as used on the Hunter T7, as the cockpit is positioned immediately between the intakes; any widening of this area would have entailed extensive (and probably prohibitive) redesign of the forward fuselage and intakes. Consequently, Hawker did the only thing possible, and extended the nose forward in a tandem seating layout, with changes to the rear fuselage including the mounting of the fin 33.3in further back and the fitting of an underfin. To maintain weathercock stability, the height of the fin was raised; this was done initially by mounting the standard GR1 fin on a fin base platform which raised it 11in. To maintain the effectiveness of the reaction control valves (RCV), the forward one was moved to near the nose, while the rear fuselage was much extended, and fitted with the rear (pitch yaw) RCV. The view from the cockpit is good. For the front-seat pilot, there is greatly improved rear vision 'over the shoulder', while the rear seat is stepped up, and gives the occupant a 10° downward view dead ahead. In line with maintaining the single-seater's operational capability, the F95 camera is moved from the nose to a position below the rear cockpit, where it is now installed next to the relocated inertial platform. A completely redesigned cockpit canopy is fitted, which hinges sideways, and the rear cockpit — which has its own windscreen — duplicates virtually all the instrumentation with the exception of the moving map display. The resulting two-seater weighs in at some 1,400lb heavier (including the extra pilot) in basic configuration. This figure includes an amount of rear fuselage ballast, to compensate for the extra weight forward, although the T2 can be flown with or without the rear-seat pilot without reballasting.

Below:
A contrast in fins – a line-up of seven Harriers seen at Yeovilton on 23 April 1980. The five Sea Harriers have the standard GR3/Sea Harrier fin with PWR antenna on the leading edge. The T4 'Z' has the original standard 'tall' fin, which is 18in higher than that on the single-seater, while T4 'Q' has the shorter GR3 fin, retrofitted when PWR was installed. *Author*

The flight testing of the two-seat prototypes did not go smoothly, and the first, XW174, crashed on 4 June 1969 following problems with the fuel system. Furthermore, despite the effective increase in fin area, this was still found insufficient to ensure directional stability under all conditions. As a remedy, the height of the fin was increased, in increments, by 6, 18 and finally 23in. The greatest extension was found to give the best handling, but would have required major restressing, so the 18in was deemed acceptable. Development flying of these fin extensions was done in the second prototype, XW175. By the time the final standard had been agreed upon, aircraft from the first production batch of 12 T2s were coming off the line, and for a time two-seaters were seen in service with varying heights of fin before the early production aircraft were retrofitted.

The T2 retains the excellent handling of the GR1/GR3, and in terms of spares and maintenance has a great deal of commonality with the single-seater. Its

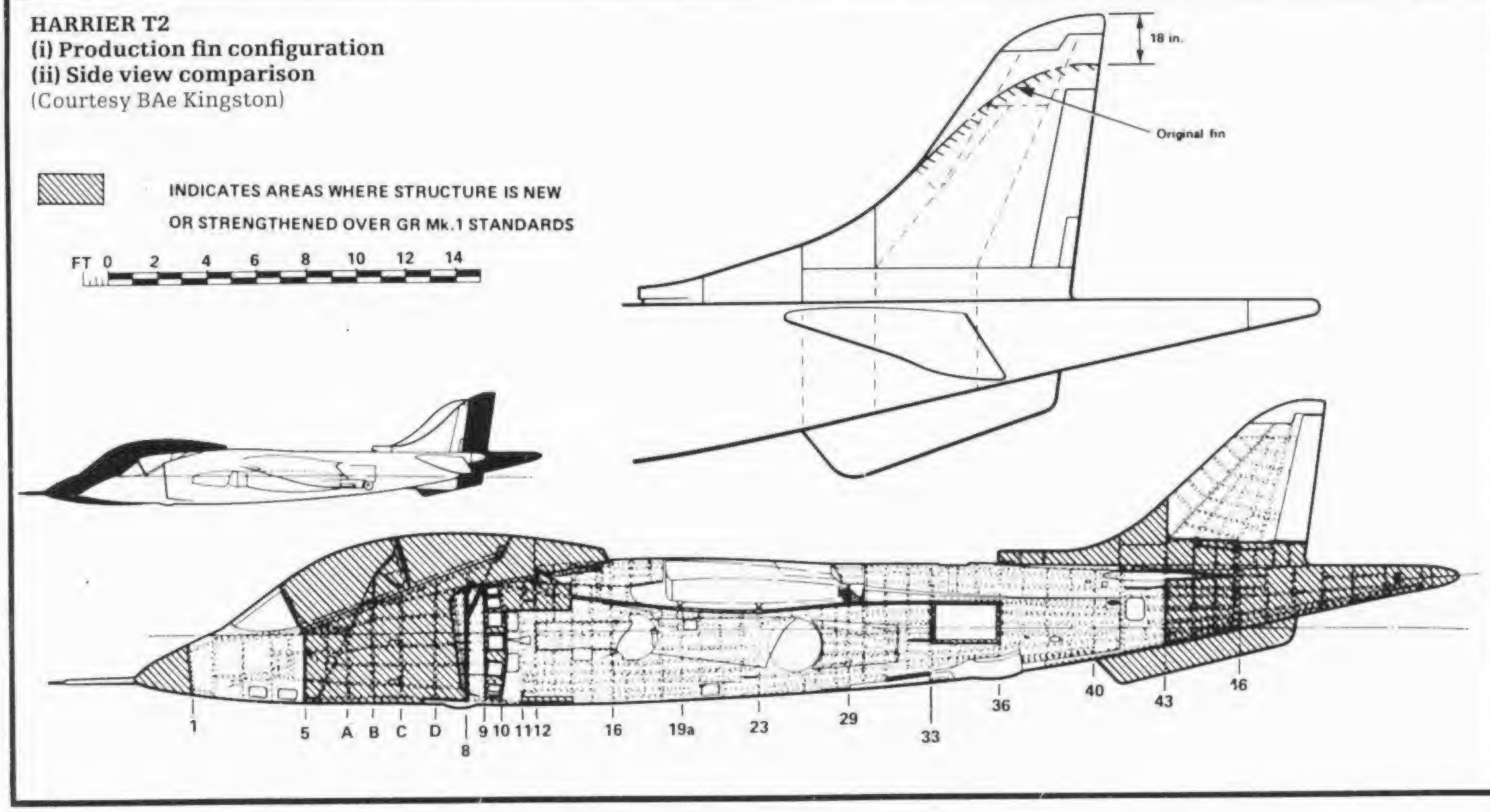
introduction to service with No 233 OCU in August 1970 considerably eased the conversion to type, and the RAF was soon converting pilots with no more than 300 to 350 total flying hours on to the Harrier. The aircraft certainly achieved its design aim of being combat capable, and even with two crew aboard its STO take-off run was only 250ft greater to become airborne than that of the single-seater with the same mission weight of fuel and ordnance. For the highest performance, the T2 can be flown single-seat after removing the rear ejection seat and the corresponding ballast in the rear fuselage. Initial deliveries went to the OCU, but by 1971 each of the frontline squadrons also had one T2 on strength, for use on dual checks, instrument ratings etc.

RAF two-seat Harriers have been through the same series of engine and operational equipment updates as the single-seaters. The original T2 became the T2A with the Mk 102; the last two aircraft of the first production batch, though ordered as T2, were completed to this standard. On receiving the

Above:
Seen at Cherry Point (date unknown), a line of TAV-8A, AV-8A, TAV-8A, AV-8A (note different fin heights). These aircraft, all on the strength of VMAT-203, still sport red/white/blue rudder stripes, which probably dates the photograph at around 1979. *L. B. Sides collection*

Below:
Spanish Navy TAV-8A 01-807 launching from the ski-jump at RNAS Yeovilton during *Escuadrilla 008's* detachment to the UK in June 1988. *BAe 8805070*

HARRIER T2
(i) Production fin configuration
(ii) Side view comparison
(Courtesy BAe Kingston)



Pegasus Mk 103, it was designated T4, and the following 14 aircraft (ordered in four batches) were all built with this engine. All two-seaters were eventually fitted with the Mk 103 and became T4, and LRMTS and PWR were fitted to this mark as they were to GR3. The incorporation of the PWR antenna in the leading edge of the fin, on either the GR3 or the T4, entailed the recontouring of the tip of the fin and an increase in its height of 5in. This has had a beneficial effect on directional stability, and as a result the T4s with PWR are being refitted with the standard GR1 fin, although still on the same fin base platform. A further sub-variant of the T4 is the T4A. Two-seaters used for conversion training do not have the same need for LRMTS, and its elimination saves weight, giving increased performance and/or endurance. 'Lightweight' — ie non-LRMTS aircraft — are designated T4A, and a number of two-seaters were converted to this standard.

All the services today flying the Harrier have purchased a batch of two-seaters, although in many cases they have followed the single-seaters into service. This was especially the case with US Marine Corps, which decided for funding reasons to delay ordering the batch of eight TAV-8A until after the final order for AV-8A had been approved and placed. The Marines' TAV-8A was derived from the RAF T4, and was fitted with Pegasus Mk 103. Its equipment fit specified the same Baseline attack system (HUD and I/WAC), Stencel ejection seats and the electrical, mechanical and weapon carriage modifications as for the AV-8A. Additionally, the US Marine Corps specified that the TAV-8A must be capable of fulfilling the Tactical Air Commander (Airborne) role, which requires the fitment of a full set of Tactical VHF and UHF radios, with independent control from the rear seat for the airborne tactical commander's use. The TAV-8A demonstrated this operational role aboard USS *Franklin D. Roosevelt* in 1976, but spent the great majority of their service use as trainers with VMAT-203 at MCAS Cherry Point.

The Royal Navy introduced the Sea Harrier into service without the benefit of a two-seat trainer, but later ordered a batch of three T4N for use by 899 Squadron at RNAS Yeovilton. These aircraft (ZB604-606) are close in standard to the RAF T4A and without LRMTS, and were preceded by a single T4A, XZ445. This aircraft, although technically ordered as part of the initial Navy Sea Harrier batch, served for many years in RAF colours with No 233 OCU at Wittering, as a Navy 'contribution' to the strength of the unit in respect of its training of Sea Harrier pilots.

Below:
T4 XW925/17 of No 1 Squadron, painted in a streaked white/green camouflage, taxies out to the runway at Tromso during Exercise 'Anorak Express' in March 1982. The aircraft is apparently being flown single-seat. *Author*

Bottom:
A T4 of No 4 Squadron makes a vertical recovery to the pad at Site 4 'Eberhard', before taxying back across the (public) road and into its hide in the forest. This photograph was taken in May 1988, during one of the RAF Germany Harrier squadrons' regular deployments 'into the field'. *Author*

The Spanish Armada

As befits a nation with a seafaring history, a mainland bordered by two oceans and a number of major islands, Spain has gone against the general trend in deciding to maintain an aircraft carrier force into the next century. Their current carrier, *Dedalo* (RO1) is the ex-US Navy escort carrier USS *Cabot* of World War 2, transferred to Spain in August 1967. Until the mid-1970s, the Spanish Armada (Navy) had used *Dedalo* solely for ASW, for which role it was equipped with SH-3 Sea King helicopters. Indeed, the Navy had no significant fixed-wing capability of any kind, save light transport and communications types flown from shore bases. In October 1972, Hawker Siddeley arranged a Harrier demonstration, with Chief Test Pilot John Farley making a series of flights from *Dedalo,* which was operating in the Mediterranean off Barcelona. His transit, unrefuelled from Dunsfold with two 330gal drop tanks, was impressive, and ended with a vertical landing on to *Dedalo*'s flightdeck. This, and the success of the US Marine Corps with its AV-8A Harrier operations from ships – especially LPH amphibious carriers and smaller LPD assault vessels – evidently impressed the Spanish enough to decide to acquire a batch of Harriers for Navy use, to provide an air defence capability aboard *Dedalo.* Whilst this vessel has proved reasonably successful for rotary-winged operations, its narrow beam and limited flightdeck – of wood planking – is less than ideal for Harrier operations, although it continued in service until June 1989.

At the time of the Spanish Harrier order in 1973, initially for six single-seat and two two-seat Harriers, relations were somewhat strained between the British and Spanish governments. As a result, the Spanish order was placed through the US Marine Corps, with the Marines' own total Harrier buy being increased accordingly. The single-seaters, variously given service designations AV-8A or AV-8S Matador (although this name seems never to have been used in practice) and referred to by the manufacturers as Mk 55, were to the US Marine Corps AV-8A specification with only minimal changes. These AV-8As

Below:
Taken during the June 1988 deployment of *Escuadrilla 008* to RNAS Yeovilton to qualify on the ski-jump prior to embarking in *Principe de Asturias,* AV-8A 01-805 flies in formation with a Sea Harrier of 899 Squadron. *BAe 8804560*

Above:
A convincing demonstration of the inherent flexibility of Harrier airpower at sea was given at Rota on 17 October 1988. Five EAV-8Bs of *Escuadrilla 009* had returned to Rota harbour on board *Dedalo* the previous week at the completion of a training cruise, but had been prevented by bad weather from flying off. On the Monday, these five Harriers simply lined up across the wooden deck of the carrier and took off vertically to fly the few kilometres back to the airfield at Rota – all this with the ship still tied up in port. *Author*

are fitted with the same Baseline nav/attack system as that fitted to US Marine Corps aircraft, but have a different radio fit to conform to Spanish Navy standards. Two two-seat Harriers were ordered at the same time, these again being (confusingly) designated TAV-8A or TAV-8S Matador, or Mk 58. Production of the Spanish aircraft was at Kingston, but they were delivered as were other US Marine Corps aircraft to the States, to be used initially in the conversion of the first Spanish pilots. During this training phase, one aircraft was lost in a formation take-off, but the remainder were delivered in 1977 to the Spanish Navy airfield at Rota near Cadiz, which has since been the base for all Armada Harrier activity, as well as being the home port of the *Dedalo*. In 1977, a second batch of five AV-8As was ordered, but this time the aircraft were delivered direct to Spain from Dunsfold.

For their primary defence role, these AV-8s were equipped from the start with two AIM-9 Sidewinder AAM, while the Harrier's standard 30mm Aden cannon were retained, these also being usable air-air. The proposed secondary role, that of ground attack and providing CAS for Spanish Marines, was similar to the primary employment of US Marine Corps aircraft, and for this reason virtually the full range of American conventional weapons can be employed. US 500lb and 1,000lb low and high drag bombs can be carried on the four underwing pylons, as can cluster bombs, while podded 2.5 and 5in Zuni rocket pods provide an anti-shipping capability. The lack of a radar was clearly a disadvantage for air superiority, but at this time the Sea Harrier – the first (and as yet only) radar-equipped Harrier variant – was still some way in the future. Whilst the Spanish decision to place their initial order for non-radar-equipped AV-8A and TAV-8A in the 1970s was thus inevitable, the mid-1980s follow-on order for 12 EAV-8Bs to form a second squadron – at a time when the Sea Harrier was in Fleet Air Arm service and Falklands-proved – is perhaps more surprising.

Harrier pilot training was carried out in close collaboration with the US forces. The first group of Spanish AV-8A pilots, all with previous helicopter experience, were given fixed-wing jet training on T-2s and A-4s with the US Navy before converting on to AV-8As, with VMAT-203 at Cherry Point, NC. This initial cadre of six pilots then returned to Rota, along with their aircraft, aboard *Dedalo* in 1977 to form *Escuadrilla 008*. Succeeding groups went through a similar initial training pattern in the USA, although some converted on to the Harrier with the RAF, joining a course with No 233 OCU at Wittering. From the third group onwards, some *ab initio* pilots were introduced, to the point where today all new Spanish pilots come straight from the Naval Academy at Marin (where all students are 'Spanish officers first'; streaming to flying duties comes at the end of the studies).

Currently, there are 10 new pilots in the States, training with the US Navy to meet the expanded Spanish requirements for aircrew for the second Harrier squadron, *Escuadrilla 009*, with the EAV-8B. As with 008, this unit was formed to operate the Harrier. Since there is virtually no Armada history of fixed-wing flying, neither unit inherited any traditions. Even so, there have only been 34 qualified Spanish Harrier pilots to date, and the Navy's needs in a steady state are for only two or three new pilots a year. Graduates awarded their US Navy wings (which they cannot subsequently wear on their Spanish uniforms) are fed into one or the other of the Rota squadrons. If going to 008, the conversion on to the AV-8A is carried out on the squadron at Rota, as the US Marine Corps no longer has any AV-8A/8Cs in service. This training requirement is a drain on squadron manpower resources. Even when *Escuadrilla 008* is embarked in *Dedalo*, one or two pilots need to remain at Rota, this from an official squadron strength of eight pilots. Only those new pilots destined for EAV-8B-equipped *Escuadrilla 009* undergo their initial conversion on to the Harrier with the US Marine Corps at Cherry Point, spending six weeks with VMAT-203 learning the basics of V/STOL flying on TAV-8Bs and AV-8Bs.

The Armada has an impressive safety record with its AV-8A, having lost only three of the 11 aircraft in 12 years, while both the TAV-8As remain in service. *Escuadrilla 008* aims to have six single-seaters and one TAV-8A available on the line at Rota on every flying day, and this is achieved without undue problems. Squadron pilots spend anything up to 20 days a month embarked in *Dedalo*, on deployments which regularly see the carrier operating in the East Atlantic area, to the Canaries or into the Mediterranean. A typical aircraft complement in *Dedalo* is five AV-8As, four SH-3s and three AB.212 helicopters, this giving an air wing with a reasonably balanced ASW, AEW and air defence capability. There are no plans to retire the AV-8A yet, and the aircraft are still relatively low-houred – the high-hours example has around 2,000hr, while 1,700hr is more typical. Spending much of their time at medium and high levels, the Spanish Harriers have no fatigue problems, and will probably remain in service until 1995 at least. A number of updates have been made to the fleet over the years, with formation flying lights added five years ago and a new CCIP weapons computer fitted, while a current programme will fit the Marconi Skyguard PWR to the single-seaters. The Spanish AV-8As have already outlasted similar aircraft in the US Marine Corps fleet, and they now look set to keep flying after the RAF retires the last of its GR3s.

A new era in Spanish carrier operations is now starting. By July 1989, the *Dedalo* had been replaced by a new, purpose-built ship named *Principe de Asturias* (R11). As with *Dedalo*, this ship is home-ported at Rota, where the naval base includes the air station (Spanish and US Navy) with its runways. Currently working up to full operational capability for the latter part of 1989, *Principe de Asturias* will be the centrepiece of a carrier battle group, with its escort of four 'Santa Maria' class (US 'Oliver Hazard Perry') frigates. This carrier, based on Adm

Zumwalt's designs of the early 1970s for a Sea Control Ship (SCS) for the US Navy, is a 16,000-ton vessel with a 575ft flightdeck, and is eminently suited to Harrier operations. Equipped with a 12° ski-jump, the *Principe de Asturias* permits a bigger embarked air wing of 20 aircraft, including ASW and AEW Sea King helicopters. The fixed-wing Harrier component will be provided jointly by *Escuadrillas 008* and *009*. The exact complement remains to be seen, but it is likely to be four AV-8As from 008, and eight EAV-8Bs from 009, this reflecting the larger number of EAV-8Bs in service and the new type's greater serviceability and availability. Operating from the carrier's deck, an AV-8B can make a STOL take-off with a 400ft run carrying five Mk 82 500lb bombs, the gun pods and a full fuel load. Another big 'plus' for the new vessel is the ability to carry out simultaneous ski-jump launches and vertical recoveries at the rear of the flightdeck, while modern deck lighting will make night operations a practical proposition – something not feasible from *Dedalo*. A series of trials by BAe test pilots Heinz Frick and Steve Thomas in August 1988 cleared the Spanish AV-8A for operations from *Principe de Asturias'* ski-jump. The pilots from *Escuadrilla 008* had qualified on ski-jump operations at RNAS Yeovilton in June 1988, on a detachment which emphasised the current closer links between the British and Spanish armed forces. Perhaps surprisingly, *Escuadrilla 008* has done no cross-decking with other NATO carriers. Rota has a dummy carrier deck marked out on a runway, but pilots who have used it were unanimous in saying that nothing could come near to simulating a real ship's deck. In the future, it is quite possible that a ski-jump will be constructed on the airfield at Rota. Spanish Harrier pilots have for many years used the flight simulator at MCAS Cherry Point, but in recent times have instead been leasing time on the Wittering GR3 simulator. Rota, though, now has a AV-8B simulator, and the past year has seen RAF GR5 pilots coming to Spain to use this facility. The wheel turns a full circle?

Formed in 1987, *Escuadrilla 009* was equipped with the first of the 12 EAV-8Bs delivered to Rota in October of that year. All were built at the McDonnell Douglas facility at St Louis, and are standard US Marine Corps aircraft. Supplied through the US Foreign Military Sales (FMS), the EAV-8Bs were flown air-refuelled across the Atlantic in flights of three by US military pilots. The last deliveries were made in September 1988, and the full 12-aircraft fleet is being used by *Escuadrilla 009* in an intensive work-up to operational capability for service aboard *Principe de Asturias* from early 1989. A deployment by the ship to the USA from the end of October until December 1988 with a number of EAV-8Bs embarked was planned to allow US Marine Corps and US Navy test pilots from Patuxent River to fly the EAV-8B from the ski-jump, to give formal clearance for unrestricted carrier operations. The EAV-8B purchase has included a good support package, and early experience with the type has shown excellent aircraft availability; at one point in early 1988, *Escuadrilla 009* with six AV-8Bs was flying more hours than the whole of 008 with its older aircraft. The role of the EAV-8B is again primarily air defence, but with maritime strike, CAS and interdiction as secondary duties. One striking difference between the two marks of Spanish Harrier is in the colour schemes. The AV-8As all carry a high gloss scheme of grey upper-surfaces and white under-surfaces, with large red/yellow

Spanish AV-8A (AV-8S) and TAV-8A (TAV-8S) Harriers

Serial	US Bu No	Old code	New code	
First batch AV-8A ordered 1973 from USA (but produced by HSA). Delivered by USAF to USA				
VA.1-1	159557	008-1	01-801	crashed 28-5-80, off Palma, flying from *Dedalo*
–	159558	008-2	–	crashed 11-6-76 in USA, pilot in training
VA.1-2	159559	008-3	01-803	current
VA.1-3	159560	008-4	01-804	current
VA.1-4	159561	008-5	01-805	current
VA.1-5	159562	008-6	01-806	current
TAV-8A, ordered 1973 from USA (but produced by HSA)				
VAE.1-1	159563	008-7	01-807	current
VAE.1-2	159564	008-8	01-808	current
Second batch AV-8A, ordered 1977 from USA. Built Kingston/Dunsfold, delivered direct to Spain				
VA.1-6	161174	008-9	01-809	current
VA.1-7	161175	008-10	01-810	current
VA.1-8	161176	008-11	01-811	current
VA.1-9	161177	008-12	01-812	crashed 30-8-86 (?) at Rota
VA.1-10	161178	008-14	01-814	current – but rebuilt after landing crash at Rota, 22-10-84

Note intentional omission of aircraft '13'.

Left:
Sortie completed and engine shut down, the pilot of AV-8A 01-804 of *Escuadrilla 008* descends the ladder to the concrete apron at Rota on 19 October 1988. *Author*

Below left:
EAV-8B 01-912 of *Escuadrilla 009*, the last of the batch of 12 ordered, returns to the pad at Rota for a vertical recovery. Clearly visible here are the square-cut 'zero scarf' front nozzles, a feature of the AV-8B/Pegasus Mk 105, and the retractable dam in the extended position. *Author*

Below:
Hovering just a few metres above the pad at Rota, AV-8A 01-814 of *Escuadrilla 008* is clearly in ground effect. By comparison with the EAV-8B in the landing configuration, the AV-8A has a much smaller area of flap and only minimal under-fuselage strakes. *Author*

national roundels and colourful squadron markings. This is in complete contrast with the *Escuadrilla 009* EAV-8Bs which are in an overall two-tone matt grey camouflage, with smaller national markings and individual codes and 'ARMADA' titling which is difficult to discern, even from a close distance. The decision to tone down the new aircraft is said to be the choice of the 'skipper' of *Escuadrilla 009*, and it is unlikely that the AV-8As will receive any similar scheme, at least in the short term.

The confusion – or at least the multiplicity – of designations for the Spanish Harriers has already been mentioned. The US system of designations has been 'bent' further in the use of EAV-8B for the Spanish AV-8B purchase – the 'E' prefix does not in any way indicate 'electronic', but merely reflects the purchasing country's name – 'Espana'. Squadron pilots seem to refer to the aircraft simply as the 'Harrier' or 'Alpha' (AV-8A) or the 'Bravo' (EAV-8B), while the TAV-8A is referred to by a Spanish name which corresponds to 'two-seater'. Budgetary restrictions seem unlikely to allow the purchase of any more EAV-8Bs in the near future, and thus an all-EAV-8B force will not be seen. Spanish pilots seem unanimous in their enthusiasm for a radar-equipped AV-8B, and joint US, UK and Spanish funding for development of such a Harrier has been mooted. Whether this might lead to a retro-fit to the existing Spanish EAV-8B fleet is questionable, but such equipment would undoubtedly improve the type's effectiveness in the air defence role. Although there is no official requirement, it seems highly likely that a small batch of TAV-8Bs will be ordered for *Escuadrilla 009* in the early 1990s.

30 Miles from the Border

'You are 30 miles from the border: how many Harriers can you see?'

Despite being strong proponents of the V/STOL concept, the RAF has never had more than four frontline Harrier squadrons, and neither the GR1/GR3 nor the GR5 has ever been adopted as its primary attack aircraft. Today, almost 20 years since the Harrier first entered service, the RAF has perfected the operational deployment of the aircraft, although in times of war probably no more than 40 (and certainly no more than 50) aircraft would be available to confront a WarPac armoured assault on the Central Front. In contrast, the Jaguar — very much a contemporary of the Harrier GR1 — was produced in greater numbers and equipped, at the peak, eight squadrons. It must be assumed that the RAF's reluctance to acquire the Harrier in greater numbers and at the expense of CTOL types has been the result of the aircraft's reduced payload-range compared with the Jaguar and Tornado. This argument, however valid, ignores the Harrier's unique advantages which result from its V/STOL ability.

'You are 30 miles from the border. How many Harriers can you see?' runs a RAF advertisement, which sums up the RAF use of the Harrier in Central Europe. Put simply, this philosophy employs the Harrier in the close air support (CAS) and battlefield air interdiction roles, flying from rudimentary sites close to the land battle. The advantage is that flying time is reduced, and with a quick turnaround a high sortie rate can be maintained for a period of days, although the logistics problems of supporting such a force in the field are not to be underestimated.

RAF Germany formed three Harrier GR1 squadrons in 1970-72, Nos 3, 4 and 20. Initially having a nominal strength of 12 aircraft each, these three were amalgamated in February 1977 into two squadrons of three flights and 18 aircraft each. A redistribution of squadrons and the continuing re-equipment programme in RAF Germany at this time involved the Harrier units moving from Wildenrath to their present base at Gütersloh, which is considerably closer to the East German border. This airfield — which is the only operational RAF airfield to have been built for the Luftwaffe — today houses Nos 3 and 4 Squadrons with Harrier GR3s and the two RAF Germany support helicopter squadrons. In addition, the airfield is the major airhead for BAOR, and sees a large number of trooping and cargo flights. HAS accommodation is provided for both Harrier squadrons, the Harrier being small enough for up to three aircraft to be housed (but not realistically operated from, nor worked upon) inside a single shelter. In common with the other three main RAF Germany operating bases, Gütersloh has over recent years been 'toned down' and some critical facilities hardened. Even so in times of tension, the Harrier squadrons would move out into the field, and Gütersloh would be vacated for the benefit of other NATO units which have need of its runways and facilities. Being so far forward, Gütersloh is within reach of Soviet SS21/SS23 long-range artillery, while the threat from Spetsnatz special forces and in-place insurgents is well understood. A comment heard at Gütersloh was

Left:
A Harrier T4 of No 3 Squadron is pictured in its hide at Flying Site 1 'Mandalay' in May 1988. *Author*

Below left:
The fuselage centreline reconnaissance pod is carried by some GR3s of No 4 Squadron to supplement the built-in nose oblique camera. The pod contains a fan of four F95 and one F135 cameras, which together give panoramic coverage of the ground overflown from horizon to horizon. The pod is seen mounted beneath GR3 ZD667 of No 4 Squadron in May 1988. *Author*

Above:
GR1 XW768/G of No 3 Squadron goes into the hover, apparently over dense forest, to recover to its dispersed site. This photograph dates from 1973, at which time the 68mm Matra rocket pod was a normal armament option for RAF Germany Harriers; today it is rarely seen, and retained primarily for the Belize duty. *BAe 731197*

that, in a modern war in Central Europe, runways were as outdated as Norman castles.

The logistics of supporting Harrier operations in the field have been refined over many years of exercises, and this capability is practised by the squadrons in exercises three times a year and in regular TACEVALs. As mentioned earlier, each squadron is organised into three flights (rather than the two flights of other fighter and attack squadrons) since the 1977 squadron amalgamations. Each flight would, in time of war, deploy semi-autonomously to its own flying site 'in the field', when the flight commander becomes the site commander. A site would support operations of six or seven aircraft, and have seven pilots and the site commander. Aircraft strength of the RAF Germany squadrons would, in times of need, presumably be bolstered by the GR3s from No 233 OCU at Wittering and their instructor pilots.

Two separate logistics groups are established at Gütersloh, one for each squadron, and everything needed to support dispersed Harrier operations is stocked on the airfield, ready for the order to move out. Six hundred vehicles are required for the two squadrons, to be driven by RAF personnel. Versatility and autonomy is the name of the game in dispersed site operations; personnel double as drivers, while drivers carry out other tasks. The whole operation is a good example of British amateurism, where the term is used to indicate adaptability without any of the negative connotations of low standards of achievement. On to these vehicles must go not only fuel and weapons, but also communications equipment, pillow tanks and tents. 'Fly away packs' of spare parts are taken into the field, together with consumables such as spare tyres and demineralised water for the Harrier's thrust augmentation system. Engine changes can be achieved in the field, although this is a major operation requiring the use of a hoist and the removal of the Harrier's wing. Whilst the aim would clearly be not to have to perform such engine changes in the field, this might well be necessary in wartime as the result of engine damage, or simply because a service becomes due following a long period 'in the field'. The Pegasus is tolerant of different types of aviation fuel, which eases the supply problem. Field canteens are established at each site, and squadrons and sites have a friendly rivalry as to who has the best meals. With creature comforts necessarily absent at such rudimentary locations, the importance of food on the personnel's morale is high, the more so the longer the deployment. Security, discipline and administration on the

site come under a RAF Regiment camp commandant, who is responsible for virtually all aspects of the site except the actual air operations. Everyone carries firearms; protection of the site is the concern of all, and groundcrew are expected to do periods of guard duty.

Whilst each squadron operates autonomously in the field, the three flying sites within one squadron will be placed within a relatively short distance of the squadron's central logistics park. If compromised, any flying site can move out to a new location, preferably under cover of darkness, in 5-6hr. An ideal arrangement is of three flying sites, a central logistics park plus three more presurveyed sites 'in reserve' should the need come to move.

To move the squadron's logistics park is a larger undertaking, and continuing operations during this period may involve support from the other squadron's logistics park, provided it is within a reasonable distance. The success of dispersed site operations depends very much on good communications, perimeter security and, of course, on the sites themselves remaining undetected. No 21 Signals Regiment is assigned to the Harrier force and deploys with it to organise all the communication network, while a Light Air Detachment of REME deploys

Above:
A one in 20 chance? Aircrew names painted under the cockpit of RAF fighters do not indicate any 'ownership' of a particular aircraft; thus, to find Flt Lt R. J. Robertshaw in an aircraft carrying his name was a fortuitous occurrence. The pilot is seen in the cockpit of a GR3 of No 4 Squadron during an operational turnaround in a hide at Site 4 'Eberhard' in May 1988. *Author*

Below:
A GR3 of No 4 Squadron gets airborne from the country road which doubles as the runway at Site 4 'Eberhard' in the Sennelager training area in West Germany. This site, which uses a short relief road as a taxiway into the forest where the hides are situated, is typical of a number of potential road/motorway operational locations for the RAF Germany Harrier force. *Author*

Above:
Having just made a vertical landing on the pad at 'Eberhard', this GR3 of No 4 Squadron has taxied back into the wooded area and shut down its engine before being pushed back into its hide by a RAF Unimog tractor. With the camouflage net 'hangar doors' closed, the aircraft is well concealed both from the ground and from aerial reconnaissance. *Author*

with field detachments for engineering support. Main fuel supplies are stocked in pillow tanks at the logistics parks, and transported to the flying sites, as required, by tanker. Being the major bulk supply item required, fuel is delivered to the general area of the flying sites by various methods. During 1987 a deployment practised loading refuelling tankers from a rail tank wagon, while the following year saw the use of a river barge. Both methods were judged successful as an adjunct to the normal road routes of supply.

For Harrier take-offs, a flying site needs a 350m metalled strip. This could well be a straight section of road, and Flying Site 'Eberhard' used in exercises is a typical example of this type of site. It is a wooded area in the Sennelager Training Area, and offers a straight stretch of road used for take-offs, with military personnel putting barriers across the highway at appropriate times to stop the road traffic. Wingtip clearances are not over-generous, but to remove trees to a greater width would be to advertise the site's existence, and climb-out is again over the trees, where the road bends. On sites such as this, the use of demineralised water for a 'wet' take-off can be worth a 1,000lb increment in thrust, which is a useful safety feature. A Mexe metal pad is laid by the engineers for landing, with double marker boards at each corner to give returning pilots a visual cue to line up centrally on the pad for a vertical recovery. No more sophisticated landing aids are installed, which clearly limits operations to daytime. Recovery is thus effected at the completion of a straight-in visual approach to the landing area, with the landing pad typically being surrounded by trees. The pattern sees a recovering Harrier going into the hover at 200ft, pointing the nose into wind at 100ft and lining up on the marker boards at 75ft. Having two adjacent pairs of markers lined up, the pilot is assured that the aircraft will land centrally on the pad, following which the Harrier is taxied straight into a hide.

The use of a metalled landing pad has the dual advantage of reducing grass ingestion into the engine and improving camouflage from the air, as bare grass is soon burnt by the hot engine exhausts when aircraft land vertically. Engineers can lay the sections of a Mexe pad rapidly, even on ground which is not 100% flat; a cardinal sin on the part of a pilot is to hover off-centre over the pad and to lift the edge with the Pegasus exhaust. One pilot who was spoken to at Gütersloh remarked that his squadron commander had become philosophical about wingtip brushes with the trees during such deployments. Although the Harrier's design of outrigger undercarriage has proven fairly robust in operation, most problems encountered happen during or soon after periods of dispersed site flying.

Above:
RAF Gütersloh is the home base of Nos 3 and 4 Squadrons, and each has sufficient HAS accommodation to protect all its Harriers. There is no doubt, though, that these two units would, in time of tension or war, move into the field to operate from dispersed sites. A GR3 of No 4 Squadron is pictured as it taxies out from its HAS at Gütersloh in June 1981. *Author*

In a wooded site such as Eberhard, concealment of the aircraft themselves is fairly straightforward. Hides are constructed between the trees, using light metal framing and draped with camouflage netting. Once an aircraft has been parked in its hide, a camouflage net is lowered to close off the front access and the Harrier really does blend into the environment. Cockpit turnaround would be normal practice in wartime, with the Harrier being connected into land lines (the socket is under the left-hand intake duct) to give a secure telebrief facility. Tasking for Harriers dispersed in the field starts with a request from the Army in the field, passed over the net and processed through the Air Support Operations Centre (ASOC) to the Forward Wing Operations Centre (FWOC). FWOC is not physically located on a flying site, and thus a daily brief is sent each morning to the flying sites, detailing the general state of the battle.

Harrier missions are thus requested by the Army in the field — mainly 1 (BR) Corps BAOR, but also by other NATO nations' forces — using a system which embodies the minimum tasking bureaucracy. By going out into the field, and with rapid turnaround (a Harrier can be rearmed and ready to go in 20min) the Harrier force can generate a much higher sortie rate than could an equivalent number of Tornados flying from the Clutch bases. The BL755 CBU (Cluster Bomb Unit) is the primary weapon for the Harrier's Close Air Support (CAS) and battlefield interdiction roles (against second echelon forces and troop mustering points). If the armourers at a flying site find a defective pylon, then the whole pylon can be removed and replaced, then transported to the logistics park for remedial action. Everything is done to keep aircraft serviceable, and to maintain the sortie rate. Even so, this would inevitably reduce after the first few days as a result of aircraft attrition and aircrew fatigue.

No 4 Squadron has (or had, until 1989) a secondary tactical reconnaissance role, and its aircraft can carry a recce pod on the centreline station. This pod contains five cameras — a fan of four F95 and one forward-facing F135 — giving horizon-horizon coverage, and complements the port oblique F95 camera fitted in the nose of all RAF GR3s. The tasking for the recce Harriers is primarily for short-range battlefield reconnaissance, with the pilot making an initial 'blind' (ie not acknowledged) radio report over the listening net shortly after having overflown the target. Straight after landing he completes a mission *pro forma*, and talks over the telebrief line. Meanwhile, the film cassettes are downloaded by an OTR team and taken by motorcycle to the Reconnaissance Intelligence Centre (RIC) and processed, to give a full report to the requestor in a stipulated (and classified) time. Two RICs, used for film processing, negative viewing, debriefing etc, are allocated to No 4 Squadron, their modular structure being built up of a number of trucks and trailers. This secondary recce capability has been a feature of No 4 Squadron's Harrier operations from the start; surprisingly, it was dropped when the GR5 started to re-equip the RAF Germany squadrons, and the two units now have an attack role only.

For training purposes, some 10 dispersed flying sites in Germany exist and are regularly activated for exercise purposes. There is no doubt that their exact co-ordinates are known to the WarPac forces, and it is certain that, in wartime, these sites would not be used. Freed from some of the niceties of peacetime respect for the German countryside and the noise sensibilities of the country's inhabitants, it is likely that the Harrier squadrons would move into the villages or even into urban areas. Wooded sections of motorways with associated parking areas could well be used, the metalled roads removing the need to lay any further Mexe strips for runway or landing pad purposes. For the best in concealment, farm outbuildings might be used, with nearby roads or fields used for operations. It has even been suggested that modern concrete buildings such as glass-fronted supermarkets or garages could provide good hides for Harriers, after suitable 'modification' by bulldozing the glass front for entry/exit, with flying taking place from car park areas or roads. Wartime contingency plans exist at Gütersloh, and a number of suitable operating sites have been presurveyed and their logistics problems considered. The locations of these sites are known to only a handful of people, and their activation would only happen in time of war; any exercise use would only compromise their security.

Sea Harriers

Affordable Air Power at Sea

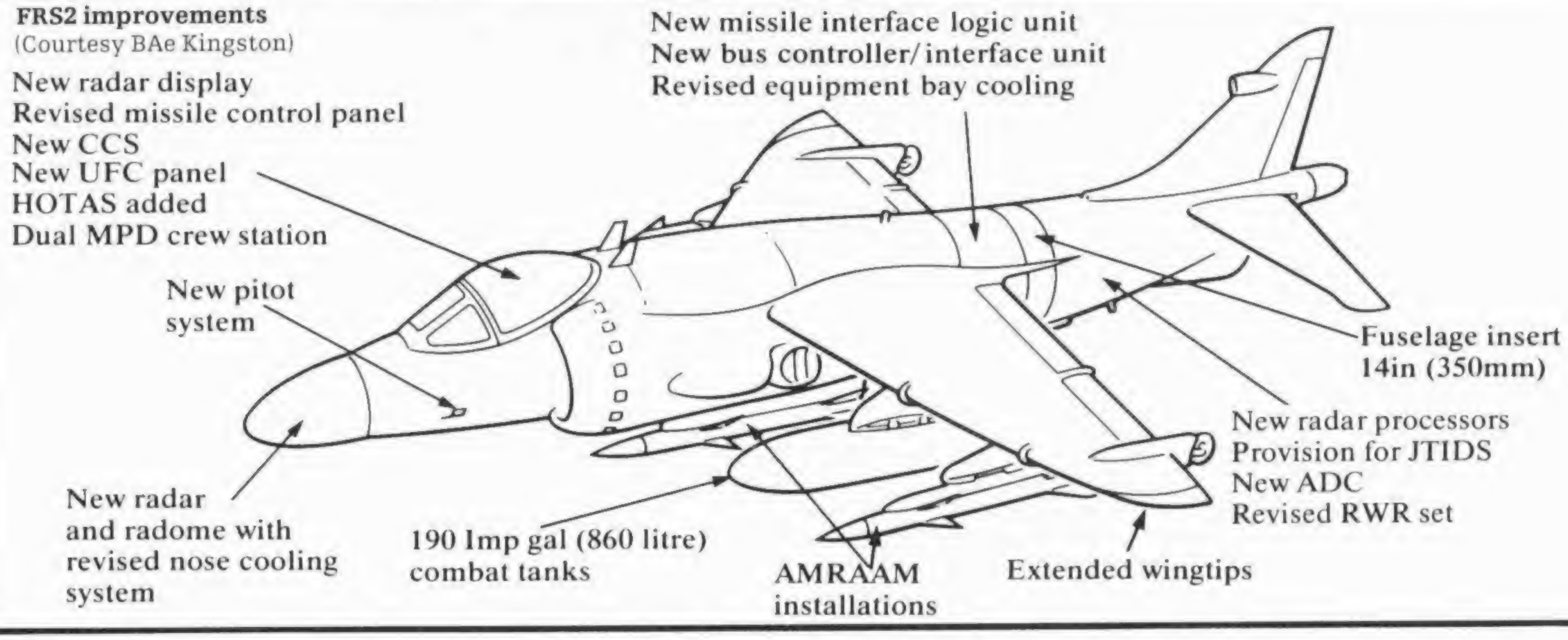
The low point in the history of the Fleet Air Arm must surely have been the final launch of a Phantom FG1 from the deck of HMS *Ark Royal* on 27 November 1978. This event marked the end of the Royal Navy's conventional aircraft carrier operations, and was for nearly two years to leave the service with no fixed-wing aircraft more potent than the Sea Devon. The end of the Navy's carrier fleet, which was maintained through the 1950s with five attack carriers using hulls laid down during World War 2, was brought about by the ever-increasing cost of building and maintaining ships capable of operating the latest (and ever-heavier) fighters and attack aircraft. Along with Britain, a number of other countries which had traditionally operated carriers retired their ships as they became obsolete and too expensive to replace. Thus Canada, the Netherlands, Australia and others reduced their naval air arms, henceforth equipping them only with rotary-winged or land-based types.

Harrier flying from ships had started as early as 8 February 1963, when Bill Bedford made the first demonstration flights aboard HMS *Ark Royal*. Further trials aboard HMS *Bulwark* with a Kestrel in 1966 demonstrated that V/STOL fighters could be integrated with conventional fixed-wing flying. Many other periods of shipboard operation proved the concept; even so, it is probably true to say that HSA continued until the late 1970s to see the Harrier's sales prospects as being primarily with land-based air forces. A pointer to the future, though, was the 1970 Service Release to allow deck operations by the Harriers of No 1 Squadron.

The replacement for the Royal Navy's attack carrier fleet was to be three smaller (16,000-ton standard displacement) 'through-deck cruisers' – intended for ASW helicopter operation, but fortuitously offering an unobstructed flightdeck. The lead ship of the class was ordered in April 1973 from Vickers Shipbuilding; this was to be HMS *Invincible*. Official Royal Navy interest in the Harrier had started shortly before this. A Naval Staff Requirement was formulated in 1971 for a seagoing version of the GR3, and HSA was given a development study contract the following year. Two major design requirements existed – to provide a radar for the aircraft's primary air defence role, and to replace magnesium in the airframe with materials which would be less prone to corrosion in the saline atmosphere of a carrier's deck. Finally, an order for 24 aircraft was announced in May 1975, to be designated Sea Harrier FRS1 (Fighter Reconnaissance Strike, reflecting its new roles). The Sea Harrier was to be a 'minimum change' development of the GR3, but the FRS1 did introduce a number of new features. The cockpit was raised 11in to provide more equipment space under the floor and a revised cockpit layout, and the pilot's view improved by the fitting of a bubble canopy. A Ferranti Blue Fox – an I-band pulse-modulated radar designed for air-air interception and air-surface search and strike – was fitted behind a pointed radome in a folding nose. A new Smiths Industries HUD was incorporated, driven by a 20,000-word digital computer. As well as generating display symbology, this also functions as a flexible air-air and air-surface Weapons Aiming Computer (WAC). A Ferranti self-aligning attitude reference platform was fitted, cross-referenced to the Decca doppler radar,

Below:
The twin-Sidewinder rail was developed during the Falklands conflict, but was not available to the squadrons until August 1982, a couple of months after the end of hostilities. It has since become standard equipment on FAA Sea Harriers, and is seen here on a FRS1 of 899 Squadron on 31 August 1985 at Yeovilton. *Author*

FRS2 improvements
(Courtesy BAe Kingston)



to perform all the navigation and endurance functions. Primary armament for the air defence role was to be a pair of AIM-9L Sidewinder AAMs, one each on the outer under-wing pylons; the twin-Sidewinder rail was a later development, started during the Falklands conflict but not available on the squadrons until later in 1982. The Pegasus engine developed especially for the Sea Harrier, which eliminates the major magnesium components, was the Mk 104. It is based on the Mk 103 in the GR3 and was similarly rated at 21,500lb thrust.

Perhaps the greatest achievement in the development of the Sea Harrier is that the 'cost' of the navalisation of the basic design amounts to under 1% of the aircraft's empty operating weight, totalling less than 100lb. To put this achievement into perspective, the navalisation of the BAe Hawk to give the US Navy's T-45 will add close on 1,000lb to give carrier compatibility.

A parallel study started at Southampton University by Lt-Cdr D. R. Taylor in 1972 was to lead to a great increase in the Sea Harrier's effectiveness aboard ship. His thesis showed the potential of launching a Harrier-type V/STOL fighter from an upward-inclined ramp. Tests with a ski-jump at RAE Bedford showed that the theoretical advantages could be achieved in practice, and between August 1977 and June 1978 tests were flown with ramp exit angles of between 6° and 20°. For the pilot, the technique was to start his take-off run along the runway (or deck), the aircraft being launched in the ideal trajectory off the ramp, and to select nozzles to 40° down within 0.5sec of crossing the ramp exit. Ten to 15sec later, he can start to move the nozzles backwards to achieve normal wingborne flight. This simple system gives the pilot a better chance of ejection should the launch go disastrously wrong (since his launch trajectory is upwards) before impact with the sea, while operations from a heavily-

Above:
The first public demonstration of Harrier ski-jump operations was given at the Farnborough air show in September 1978, when Sea Harrier FRS1 XZ450 made daily take-offs from the 165ft 15° ramp. *Author*

pitching flightdeck can now be safely accomplished without the chance of striking the sea. Operationally, the gains are dramatic. For any given take-off weight, the ski-jump allows launch speeds of 25 or more knots less than from a flat deck. This translates to a 50% shorter take-off run, or to a 30% increased weapon and fuel load, while the need for the ship to attain high into-wind speeds during launch phase is reduced. The RAE Bedford tests were conclusive enough for the Royal Navy to decide to fit its new through-deck cruisers with ski-jumps, although the first two examples (*Invincible* and *Illustrious*) would only initially have ramps with 7° exits because of physical constraints of the ships' design and the placement of the Sea Dart launcher. HMS *Hermes* was similarly to receive a 12° ski-jump in its 1979-80 refit.

First flight of a Sea Harrier was made by XZ450, the first production aircraft, at Dunsfold on 20 August 1978. By this time, Sea Harrier production orders had been increased to 34, this figure including three pre-production aircraft (which in fact followed XZ450 into the air). Development flying progressed quickly, and the handover of the first example (XZ451) to the Navy on 16 June 1979 was marked by a ceremony at Dunsfold. By this time, BAe test pilot Mike Snelling had already made the first Sea Harrier deck landing, this occurring on HMS *Hermes* on 14 November the previous year.

To build up experience rapidly of operating any major new aircraft type, the Fleet Air Arm forms an Intensive Flying Trials Unit (IFTU), numbered 700 Squadron with a letter suffix. In the case of the Harrier, the squadron was 700A. It is uncertain whether the 'A' suffix reflects the fact that the sequence A-Z had been largely exhausted, or if it was an example of Navy humour – 'A'

Above:
ZA195 is the first prototype Sea Harrier FRS2, having been reworked from a FRS1 at Dunsfold. It made its first flight in this form on 19 September 1988, and successful early flight trials led to the award of a £120 million contract in December 1988 to cover the conversion of all the FAA FRS1s, starting in October 1990. *BAe*

Bottom:
It has not proved possible to obtain a photograph of an operational Indian Navy Sea Harrier FRS51, all available material apparently having been taken in the UK prior to delivery or in use with the Indian Navy Training Unit at Yeovilton. IN601, the first of the initial Indian FRS51 order, hovers over the Farnborough runway in September 1982. It carries the 'tiger' markings of No 300 Squadron. *Author*

for 'arrier, following on from 700L (with Lynx) and 700P (with Phantoms). Either way, 700A Squadron formed at RNAS Yeovilton on 26 May 1979, and received its first aircraft on 18 June, when XZ451 was delivered. Equipped (at the peak) with five Sea Harriers, the unit developed operational techniques for V/STOL flying from carrier decks, and embarked for trials aboard HMS *Hermes* in October. Finally, and with its job done, 700A disbanded on 31 March 1980, passing its aircraft at Yeovilton to a new Headquarters Squadron, 899. The squadron's badge, featuring a white bird in a large red 'A', was painted out on the fins of the Sea Harriers, to be replaced by the 'mailed fist' emblem of 899, last seen on Sea Vixens.

Navy plans at this time were to form 899 and three frontline Sea Harrier squadrons, for which the numbers 800, 801 and 802 had been provisionally allocated. No 800 recommissioned at Yeovilton on 23 April 1980 as the first of these. To embark in the carriers of the 'Invincible' class, the squadrons were small by the standards of previous FAA frontline units. A typical Air Group was to comprise five Sea Harriers and nine ASW Sea Kings, and thus the establishment of each frontline Sea Harrier squadron was set at five aircraft. The Headquarters Squadron, 899, had a larger complement of aircraft to equip it for its training role. Although it was not generally envisaged for its aircraft

Above:
Sea Harrier FRS1 XZ496/002 of 801 Squadron, is seen tied down to the forward deck lift of HMS *Invincible* during the carrier's operational work-up in June 1981. *Author*

Below:
A Sea Harrier FRS1 of 801 Squadron recovers to the flightdeck of HMS *Ark Royal*. This aircraft is in the toned-down, post-Falklands overall dark sea grey camouflage scheme, with checker-board rudder markings. *Crown Copyright, Ark Royal A88/1651/09*

to go to sea, four Sea Harriers of 899 made the world's first ski-jump launches at sea when flying from HMS *Invincible* in November 1980, straight after the Sea Harrier had received its CA Release.

Meanwhile, HMS *Invincible* had been accepted by the Navy on 19 March 1980, and had been working up prior to commissioning on 11 July 1980. By this time, 14 Sea Harriers had flown. No 800 Squadron embarked in *Invincible* for the first time in January 1981, its aircraft receiving the tail-code 'N' atop the fin to indicate attachment to the carrier. The squadron did much work in development tactics for the Sea Harrier, and integrating it into air operations from *Invincible*. Although the Navy changed the designation of the class to anti-submarine warfare aircraft carrier (CVS), the embarked Air Group gave a good all-round capability, from ASW through air defence, reconnaissance, anti-shipping, attack and strike. Only long-range attack and (as was to be demonstrated so vividly) AEW cover were not provided for, while the ship's own fixed defences were also considered 'light' by current standards.

On 16 June 1981, HMS *Invincible* was declared operationally ready for service, and by this date the embarked Sea Harrier squadron was No 801. This second frontline squadron had commissioned on 28 January 1981, home-based at Yeovilton, under the command of Lt-Cdr N. D. Ward. Its Sea Harriers were aboard for the ship's Operational Readiness Inspection (ORI) in June of that year, and were in fact the first to be fitted with the full weapons system. On a visit by the author to *Invincible* off the Scillies in June 1981, the squadron CO 'Sharkey' Ward vowed that the Sea Harrier was 'a great fighter weapons system' and 'able to outfly any aircraft in the world at low speed'. As well as the ORI, the ship took part in NATO exercises 'Ocean Venture' and 'Ocean

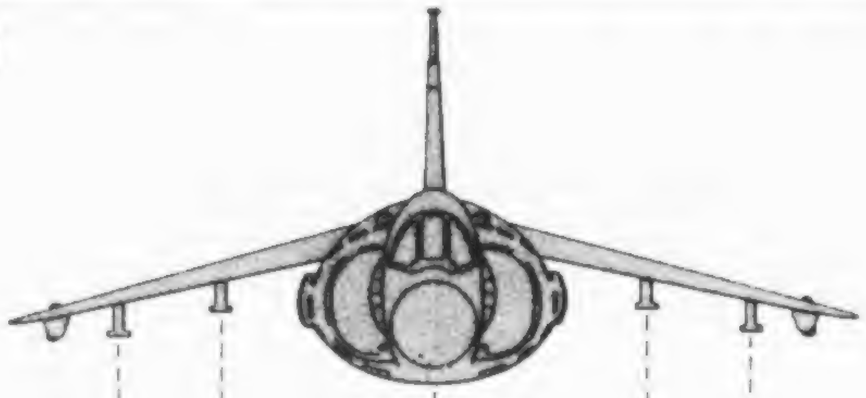
Above:
A Sea Harrier FRS1 of 800 Squadron is pictured on the flightdeck of HMS *Hermes* on 12 June 1983, during Exercise 'Ocean Safari 83'. Today, this carrier continues to fly Sea Harriers, but under the Indian flag. *M. Horseman*

Above right:
The elaborate (and shortlived) tail markings of 800 Squadron, with a trident and crossed swords on a bright red background, seen at Yeovilton on FRS1 XZ458 on the occasion of the squadron's commissioning on 23 April 1980. *Author*

Safari' in 1981, followed by Exercise 'Alloy Express' off Norway in March 1982. These exercises proved the ability of the Sea Harrier to launch and recover in sea states which would prevent traditional attack carriers from operating aircraft, while rapid take-off rates demonstrated the launching of four aircraft in under a minute. Meanwhile, 800 Squadron had embarked in HMS *Hermes* (now equipped with ski-jump), again with only five aircraft despite the ship's ability to stow and operate many more. Whilst the Royal Navy was demonstrably building up its carrier fleet and had clearly acquired a unique capability in the Sea Harrier squadrons, the perceived need for defence economies was continuing to affect the force. Plans were afoot to sell *Invincible* to the Australian Navy at a 'knock-down' price (with the understanding that this would be accompanied by a Sea Harrier order), while *Hermes* was to be retired once the third and final 'Invincible' class carrier HMS *Ark Royal* became operational. By this reckoning, the need was eliminated for a third frontline Sea Harrier squadron, and 802 never reformed.

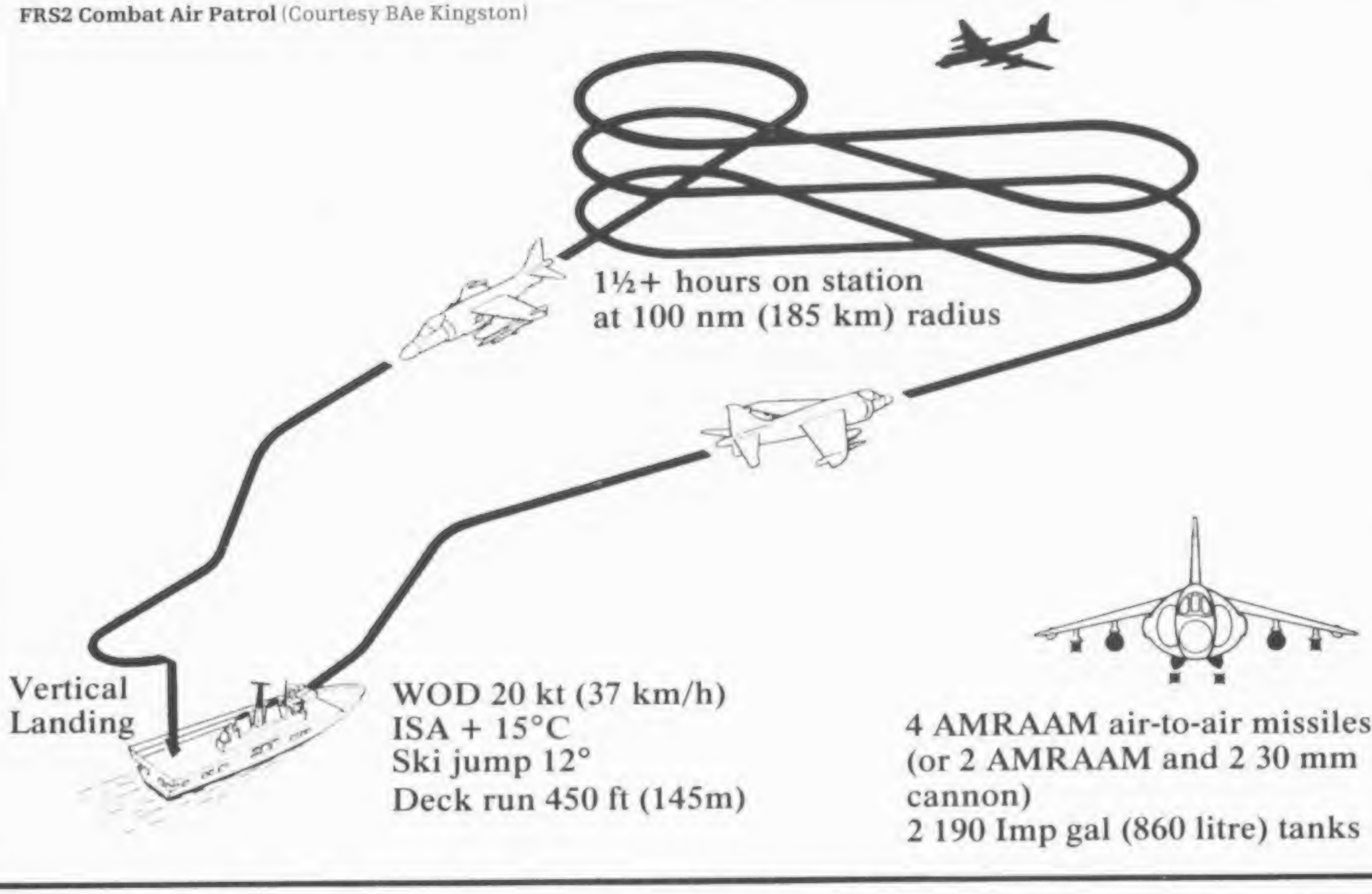
The Navy's planned force of two carriers in service at any one time, each with an embarked Air Group comprising Sea Harriers and ASW Sea Kings, was ideal for fulfilling NATO require-

Armament (Courtesy BAe Kingston)



30mm Aden guns or new 25mm guns	Mk 83 LDGP free fall 1 000lb
Drop tanks (100, 190, 330 Imp gal)	Mk 82 Snakeye retarded 500lb
1 000 lb bombs (free fall/retarded)	Mk 82 LDGP free fall 500lb
Cluster bombs	Mk 81 Snakeye retarded 250lb
Rocket launchers 68 mm (Matra 115/116)	Mk 81 LDGP free fall 250lb
Flares (Bofors Lepus)	LAU-69A rocket launcher
Practice bombs (free fall/retarded)	LAU-10A rocket launcher
Sidewinder, Magic AAMs	LAU-68A rocket launcher
Martel or Harpoon ASMs	Mk 77 firebomb
Sea Eagle	APAM cluster/Mk 7 dispenser
AMRAAM	Rockeye 11 cluster/Mk 7 dispenser
ALARM	PMBR practice bomb rack

FRS2 Combat Air Patrol (Courtesy BAe Kingston)



ments in the North Atlantic. What was never foreseen – and apologists say could never have been predicted – was the Argentinian invasion of the Falkland Islands in April 1982 and the decision to dispatch a British Task Force to the South Atlantic to contest the issue. To say that the Sea Harrier (and Harrier, as already related) played a major role in 'Operation Corporate' is, quite simply, an understatement. Without the Sea Harrier, the Task Force would have been unable to provide its own air defence while in range of land-based – and possibly carrier-based – Argentinian aircraft. In short, the Task Force would never have been sent.

Only two carriers, *Invincible* and *Hermes,* were available for operational use in April 1982; *Illustrious* was still fitting out, while *Ark Royal* was some years from service. Of the 34 Sea Harriers ordered for the Navy, 31 were available (the last two were still on the production line, while one had already been written off). Of these 20 were on the strength of Nos 800, 801 and 899 Squadrons, and following news of the Argentinian landings of 2 April, all three units worked flat out to get their aircraft serviceable. By late afternoon of 2 April, 800 Squadron had embarked eight Sea Harriers in *Hermes* at Portsmouth, these including its own five aircraft and three more from 899 Squadron. Three more Sea Harriers embarked on 4 April, these coming from storage at RAF St Athan (ZA192, ZA193)

and from Boscombe Down (XZ450, a Sea Eagle development aircraft). A twelfth aircraft was flown on to *Hermes* on 5 April in the English Channel, after the carrier had departed Portsmouth earlier in the day, bound for the South Atlantic. *Invincible,* meanwhile, was being readied to sail, and eight Sea Harriers of 801 Squadron (the unit's wartime complement, increased by the addition of three aircraft from 899) were flown on at Portsmouth. En route, the Sea Harriers were repainted, to lose the colourful markings which had so recently been applied. The red/white/blue roundels were replaced by smaller red/blue ones of Type 'B', while the white aircraft undersides were repainted to give an overall dark sea grey scheme.

One of the surprises of the early days of the Falklands conflict was the formation of a new Sea Harrier squadron. On 7 April 1982, 809 Squadron was re-formed, and the unit commissioned at Yeovilton the following day. By the time of the departure of the Task Force, 899 Squadron was devoid of aircraft and pilots, these having been integrated into the squadrons aboard *Hermes* and *Invincible*. No 809 had the task of supplementing the other two frontline squadrons in the Task Force, and its equipment was drawn from aircraft in storage, under maintenance or being completed at Dunsfold. Pilots were drawn from experienced Harrier/Sea Harrier aircrew from exchange postings, desk jobs or the Royal Air Force, under the command of Lt-Cdr

Tim Gedge, the former CO of 800 Squadron. A total of eight pilots and eight Sea Harriers were brought together for an intensive period of preparation and work-up in mid-April. On 30 April, the squadron dispatched two groups of three Sea Harriers to Ascension Island, staging via Banjul in company with RAF Victor tankers. They were followed by the final pair, which left on 1 May. The last leg of the transit to the Falklands Total Exclusion Zone (TEZ) was made cocooned as deck cargo aboard the *Atlantic Conveyor,* along with RAF Harrier GR3s and Wessex and Chinook helicopters. During the transit, one Sea Harrier was kept on alert, armed and fuelled, ready to intercept any Argentinian overflights. By 18 May, the *Atlantic Conveyor* was within flying range of the carriers in the Task Force, and the eight Sea Harriers flew off to *Invincible* and *Hermes*. Once on board, both aircraft and crews were effectively integrated into the operations of 800 and 801 Squadrons, and 809 Squadron ceased to exist as an independent operational unit.

With the Task Force steaming south, development work continued in the UK using the small number of available Sea Harriers. Although the Sea Harrier had provision for carrying AIM-9L Sidewinders, the weapon had not yet been issued to the squadrons, and some small modifications were made to the HUD/WAC to facilitate its use. In addition, design was pushed ahead of a twin-Sidewinder launcher, while further supplies of AIM-9L were hurriedly obtained from the US government. Clearance was obtained for the use of the BL755 cluster bomb, along with the 2in rocket pod for possible anti-armour role. Some of the Sea Harriers aboard *Hermes* did not even have the Blue Fox radar fitted when embarked, and much work was done on board the carrier before reaching the TEZ to ensure that the aircraft were ready to fight when the time came. A Tracor ALE-40 chaff/flare dispenser unit was mounted in the rear fuselage, at panel 69; loosing off chaff or, in dire emergency, flares can be the difference in combat between survival, ejection or worse.

The intended use of the embarked aircraft was for Sea Harriers to provide the Combat Air Patrol above the Task Force, while the non radar-equipped RAF GR3s would specialise in ground attack. Both variants were fitted with F95 cameras (that in the Harrier facing to port, while the Sea Harrier's faces to starboard) and thus capable of photo reconnaissance, although the Sea Harrier's radar was useful for detecting ships. Until the arrival of the GR3 aboard *Hermes* on 18 May, the Navy's Sea Harriers had to carry out all these roles, starting in earnest on 1 May, when nine aircraft of 800 Squadron flew from *Hermes* to attack Port Stanley airfield. On the same day, aircraft of 800 and 801 Squadrons had a number of combats with Argentinian fighters, and achieved three Sidewinder kills against a Mirage, a Dagger and a Canberra. These early engagements did much to establish the Sea Harrier's ascendancy — a true 'air superiority' — and the Argentine Air Force was henceforth less willing to engage intentionally in air-air combat with the Royal Navy. Achieved by a force of just 20 Sea Harriers, this was an important victory. The Sea Harrier also proved capable of operating in the worst weather conditions and sea states, being able to maintain the all-important CAP whenever necessary. An important tactical aim in the early part of the conflict was to deny the Argentinians the use of Port Stanley airfield, at least to the point where they could not base fighter aircraft there. A number of bombing raids were made in May, starting with the first Vulcan 'Black Buck' raid of 1 May. Only partly successful, the Vulcan raids were supplemented by Sea Harrier attacks with thousand-pounders, CBUs and retarded bombs. The Port Stanley runway proved to be a difficult target to penetrate, and the airfield was well protected by radar-laid AAA and a variety of SAM types. While the British forces never succeeded in putting the runway out of action to STOL types such as the C-130 Hercules, the Argentinians never felt confident enough to base fighters on the field.

The Sea Harriers proved capable of maintaining a high sortie rate; maintainability was high, and 10min turnarounds could be achieved when necessary. Freed from the peacetime constraints, some novel operating techniques were developed. On 1 June, two Sea Harriers of 801 Squadron were vectored on to an Argentinian C-130 off San Carlos. The target was tempting, but both Sea Harriers were low on fuel, and could not risk being unable to return to *Invincible*. A radio call to the fighter-director frigate HMS *Minerva* ascertained that the assault ships *Fearless* and *Intrepid* were in the area. Both were equipped with helicopter decks, and were capable of refuelling the Sea Harriers, should the need arise. Freed from worry as to their ability to return to the carrier, Lt-Cdr Ward attacked the C-130E with Sidewinders and cannon and watched as it fell into the sea, the first Argentinian Hercules to be destroyed. Despite low fuel, the

Left:
Recovering to a rain-covered runway, Sea Harrier FRS1 XZ460/253 of 800 Squadron almost disappears into a cloud of spray in front of the crowds at Farnborough, 5 September 1980. By this time, 800 Squadron's aircraft had acquired HMS *Invincible*'s tail code 'N', which was replaced by *Hermes*' 'H' by spring 1981 when the squadron changed ships. *Author*

Below:
Sea Harrier FRS1 XZ451 of 700A Squadron is seen at RNAS Yeovilton in 1979. The tail code 'VL' denotes Yeovilton as the unit's home base, although its aircraft did embark for operational trials in HMS *Hermes* in October 1979 in the Irish Sea. *Phil Boyden*

Above:
FRS1 XZ499 of 809 Squadron, deployed via Ascension Island and *Atlantic Conveyor* to the TEZ in late April/early May 1982. The aircraft then joined 800 Squadron aboard HMS *Hermes* and was coded '99', although in this shot the 809 Squadron 'Phoenix' badge is still visible on the fin. *BAe 824156*

pilots elected to return to *Invincible*, landing back with no more than 200lb remaining.

This engagement highlighted one of the Harrier's strengths, the ability to operate off virtually any ship with a helicopter platform. On the other hand, the Argentines flew escorted C-130 resupply missions at night into Port Stanley, while the Royal Navy had severe problems in launching intercept missions against them, as the Sea Harrier radar lacked the necessary look-down shoot-down capability. Sea Harriers of 800 Squadron flew the final air attack on Port Stanley on 11 June prior to the ceasefire of 14 June. Following the cessation of hostilities, 801 Squadron continued to fly CAP and maintain an air defence presence both from *Invincible* and from ashore at Port Stanley. It was announced at this time that *Hermes* was to be the first to return to the UK, leaving the Falklands in early July. *Invincible* remained on station until 28 August, when it was relieved by the newly-commissioned HMS *Illustrious*, with 809 Squadron and its Sea Harriers embarked. The two sister ships met at sea, the resulting photographs being featured in newspapers the world over. *Illustrious'* Air Group included two prototype Airborne Early Warning Sea King helicopters; had such a capability been available in the actual conflict a few months earlier, some of the Navy's ship losses could certainly have been avoided. Finally, once the necessary 2,000ft extension to the Port Stanley runway to allow the operation of RAF Phantoms had been completed, the need for *Illustrious'* Sea Harriers was lessened, and the ship returned to the UK via the USA. Following the squadron's return to Yeovilton, 809 Squadron was disbanded again, and its aircraft put back into the system for maintenance and eventual reissue to other units.

The Falklands campaign had been fought and won, but at a cost. Losses in the South Atlantic amounted to six Sea Harriers as well as four RAF GR3s; significantly, though, no aircraft had been lost to the enemy in air-to-air combat. The Sea Harrier had proved capable of carrying out a multiplicity of roles, while its serviceability was better even than advertised. Taking the Sea Harrier and a Harrier together,

1,650 sorties were flown within the TEZ, for an overall loss rate of 0.61%. Ground-based defences had claimed five of the 10 aircraft lost, while the remainder (apart from GR3 XZ989, which crashed on landing at San Carlos) were a direct result of the sometimes appalling Atlantic weather conditions in which the carriers were forced to operate. Despite their small numbers, the aircraft had proved capable of outfighting any Argentinian type, and the two Sea Harrier squadrons established an effective CAP around the Task Force. Twenty Argentinian aircraft 'kills' were confirmed, with the Sidewinder accounting for 16 of these. On the debit side, the Navy's force of Sea Harriers was clearly insufficient to allow any long period of wartime attrition; hence the addition of the RAF GR3s. The Blue Fox radar, while performing 'to spec', lacked the look-down capability for use against low-flying targets. To be fair, these deficiencies had been recognised before the departure of the Task Force, but were brought into sharp relief by hard operational experience. Most importantly, the Sea Harrier concept had been proved in an operational environment, and those detractors who saw it merely as an adept airshow performer now had to take the aircraft seriously.

The euphoria of the homecoming of *Hermes* and the rest of the Task Force did not disguise the fact that Operation 'Corporate' had taught some hard lessons, cost the lives of many British servicemen and caused the loss of much equipment. Plans to sell off *Invincible* were quietly abandoned. Even so, despite the Navy's aim of maintaining a force of three 'Invincible' class carriers, the third Sea Harrier squadron has not been formed, as a result of the plans for only two of the ships to be at sea at any one time. A direct result of this has been that 800 and 801 Squadrons are spending a lot of time embarked; the latter spent eight months embarked in *Ark Royal* in 1988, although this figure was unusually high and partly a result of the 'Outback 88' deployment to Australia. An order for a further batch of 14 Sea Harriers was announced on 1 July 1982, at least partly to replace the seven (including one which crashed at Yeovilton during the work-up in May 1982) lost in 'Operation Corporate'. A second reorder was made public in September 1984, to bring total Navy procurement to 57 FRS1s.

HMS *Hermes* was retired after the Falklands conflict, although it was purchased by India and re-entered service as a Harrier carrier under the Indian flag. 'Operation Corporate' had shown the need for a larger embarked squadron of eight Sea Harriers to be capable of maintaining an effective CAP over long periods. The final order of nine FRS1s was intended to allow the frontline squadron strength to be increased to this figure. The official date for the establishment of eight-aircraft squadrons was April 1987, but in fact the strength had been building up towards this figure over the previous year. HMS *Invincible* went in for a refit in 1986, this to include improved and enlarged accommodation for the personnel and aircraft of the Air Group, and also to fit a ski-jump with the optimum 12° exit. The vessel emerged from the refit late in 1988, at which point *Invincible* resembled more closely *Ark Royal*, the third ship of the class. Next of the class to go for refitting will be *Illustrious*, which will undergo similar modifications.

The government's predictions of there being only two carriers in service at any one time have thus been proved largely correct, but the result has been an amount of reallocation of the frontline squadrons to different Air Groups. No 800 joined *Illustrious* from *Hermes*, and was still carrying that ship's 'L' tail code in late 1988. No 801, meanwhile, moved to *Ark Royal* from *Invincible* when the latter went in for refit. The next change will presumably see 800 Squadron joining *Invincible*, when *Illustrious* goes into dock for an extended period for refit in 1989.

Various exercises and deployments in recent years have taken Royal Navy carriers outside the normal NATO operating areas. Exercise 'Orient Express' in late 1983 took *Invincible* to the Indian Ocean, South China Sea and to Australia, while 'Outback 88' saw *Ark Royal* sailing to Australia, to take part in the bicentennial celebrations. 'Purple Warrior' in November 1987 was to some extent an exercise rerun of a Falklands scenario, and required the task force to rescue the nationals and dependents of a mythical Common-

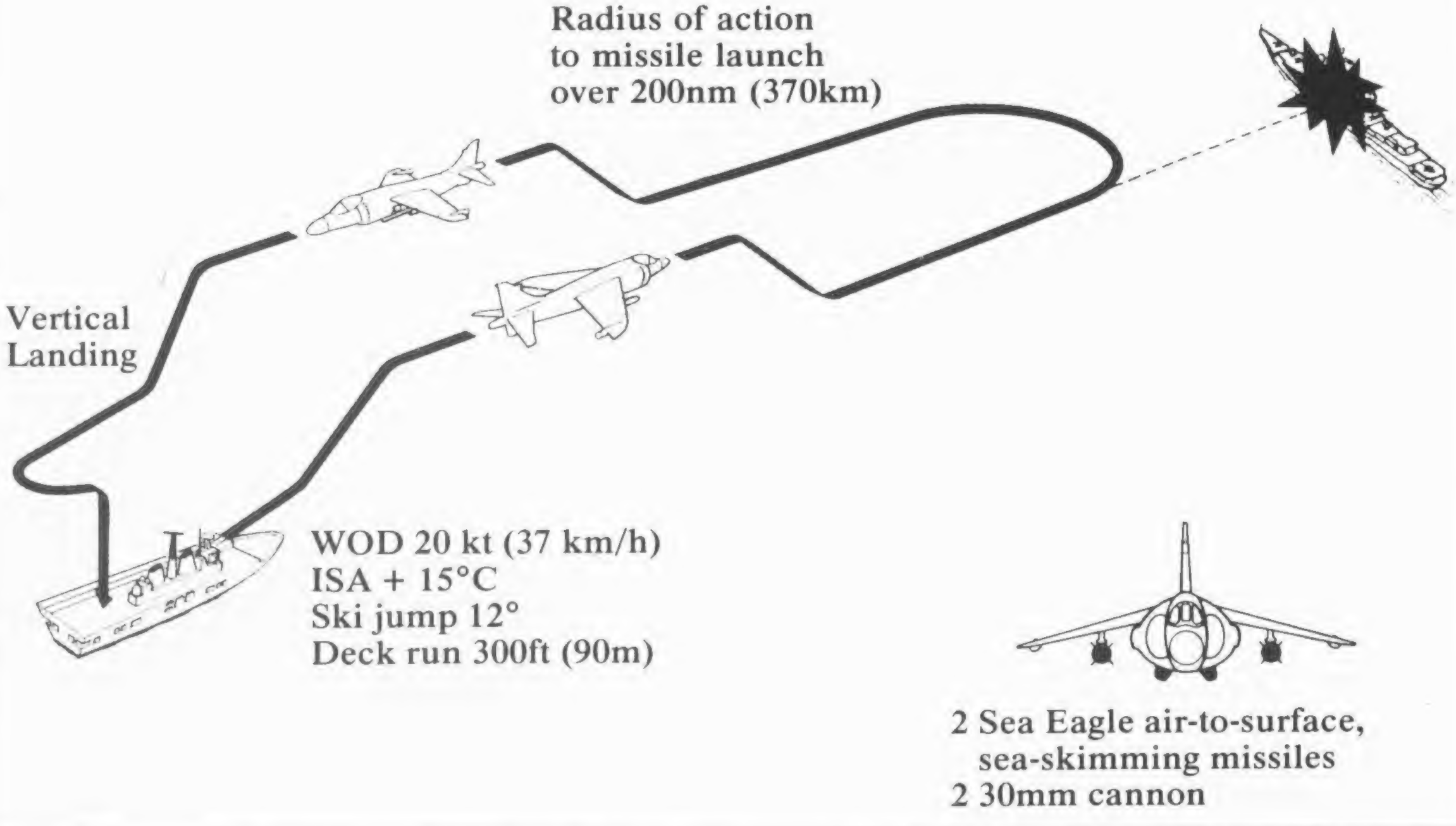
Above:
Sea Harrier FRS1 XZ457/715 of 899 Squadron gives an aerobatic display at Farnborough 86. *Author*

Below:
FRS1 XZ455/712 of 899 Squadron cleans up after take-off at Farnborough, September 1988. This aircraft is in the now standard Navy overall dark sea grey colour scheme, with reduced-size red/blue roundels and black squadron markings and codes. *Author*

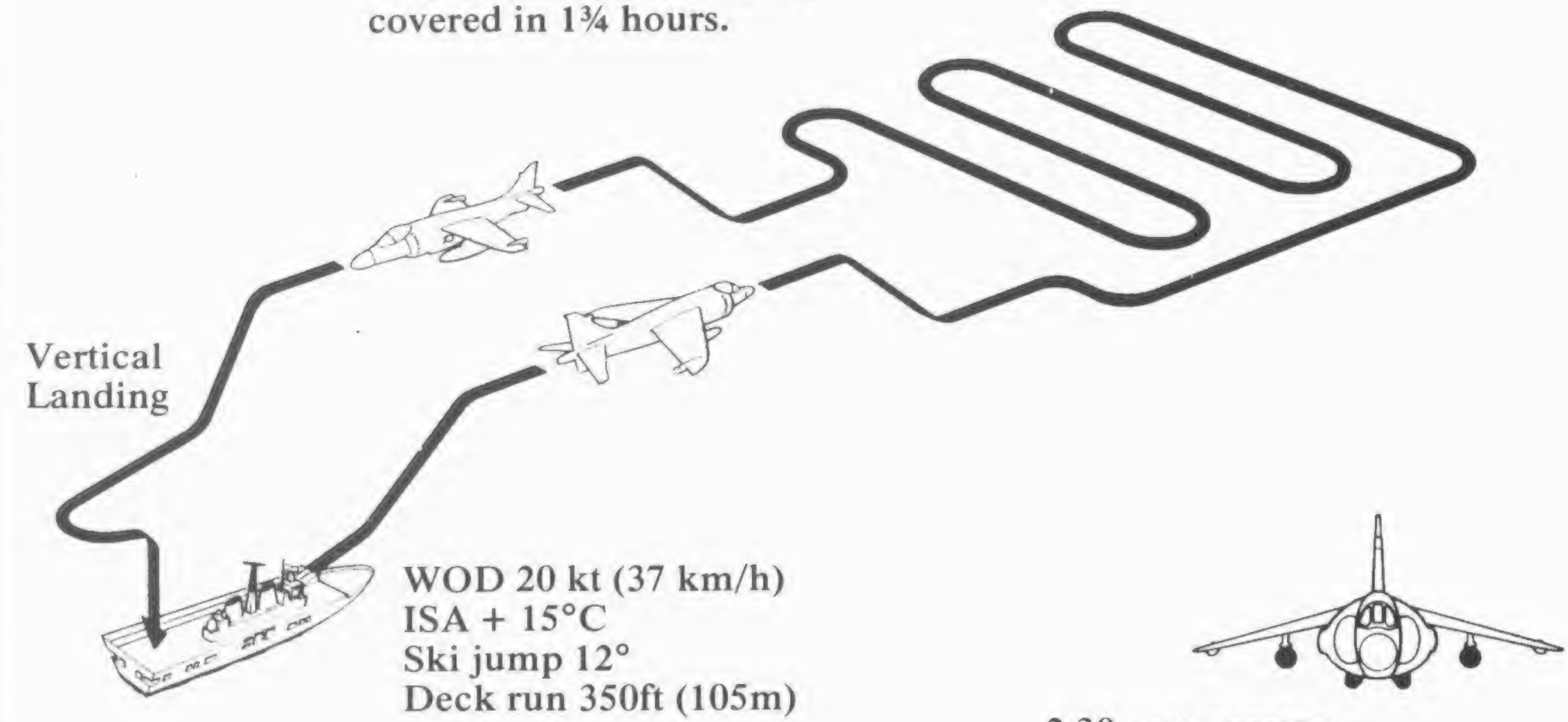
wealth island nation. The task force centered around *Ark Royal*, with an Air Group bolstered by the addition of RAF GR3s from No 1(F) Squadron. Despite the difference in primary role between the FRS1s and the GR3s, the RAF aircraft can provide useful additional CAP capability when embarked, armed with two AIM-9L Sidewinders.

Sea Harrier squadrons are now fully capable of operating Sea Eagle, the new active radar anti-shipping missile which first entered service with the RAF Buccaneer maritime squadrons. The arrival of the Sea Eagle has given the Sea Harrier capability in another role, with a stand-off range which makes possible attacks on even heavily-

FRS2 Surface Defence (Hi-Lo-Hi) (Courtesy BAe Kingston)



FRS2 Reconnaissance and Probe (Courtesy BAe Kingston)



armed naval vessels from outside the range of their fixed weapons systems. For the Sea Harrier pilot, the missile has meant a period of work-up to practise and perfect Sea Eagle attack profiles, this to add to the primary air defence and secondary reconnaissance and strike roles. More even than with the RAF Harrier, the Royal Navy Sea Harrier pilot is the veritable 'jack of all trades', which must qualify his aircraft as a true multi-role type.

As has been the case with virtually every service introduction of the Harrier family, the Fleet Air Arm did not have any two-seaters initially. One T4A (ie non-LRMTS-equipped T4) XZ455 was nominally included in the initial Navy order for FRS1s, but this served with No 233 OCU at Wittering where Navy Sea Harrier pilots did their initial Harrier conversion. Three T4Ns (ZB604-606) — effectively T4As with equipment more closely resembling that in the FRS1 — were delivered from September 1983 to January 1984, serving with 899 Squadron. These aircraft are pure trainers, and are not radar-equipped; they are thus non-operational, and are not carrier compatible (if only because their extra length compared with the FRS1 would not allow them to fit on an 'Invincible' class deck lift). Now that 899 Squadron has been tasked with training all Navy *ab initio* Sea Harrier pilots (as from 1 January 1989), this Headquarters Squadron has been expanded, and may well increase its aircraft strength to include a number of RAF T4s.

Despite earlier sales predictions, foreign nations were slow to order the Sea Harrier. To date, only the Indian Navy has signed, purchasing two batches totalling 16 FRS51 single-seaters and three T60s, together with the Sea Eagle missile. The FRS51 is very closely related to the FRS1, differing only in the provision of gaseous oxygen, the radio fit and the ability to carry Matra M550 Magic AAMs. In case anyone is still left wondering, India was the customer mysteriously referred to by BAe in 1980 as the 'Asian country' having ordered Sea Harriers. No 300 'Tiger' Squadron at Goa-Dabolim received these aircraft, after the Indian pilots had trained with the Royal Navy at Yeovilton from late-1982. Two aircraft carriers are in Indian Navy service, both ex-Royal Navy — INS *Vikrant* (ex-HMS *Hercules*) and INS *Viraat* (ex-HMS *Hermes*, complete with 12° ski-jump). At early 1989, the final aircraft of the second batch were still coming off the Dunsfold line, and a further Indian Sea Harrier order is expected, to provide sufficient aircraft for a second squadron.

What may well prove to be the final Harrier variant developed in the UK is the Sea Harrier FRS2, a much-improved FRS1, for the Royal Navy. Plans to carry out a mid-life update for the Royal Navy's fleet date from 1983 (ie post-Falklands), this to incorporate a look-down shoot-down radar to replace Blue Fox and a radar-homing medium-range missile. The radar is to be the pulse doppler Ferranti Blue Vixen, which will offer track-while-scan and multiple target engagement and total compatibility with the AIM-120 AMRAAM missile, four of which can be carried. Viewed from the exterior, the FRS2 will be recognisable by a more rounded nose radome and an extended (by 14in) rear fuselage, as well as extended wingtips. In the cockpit, all time-critical weapon system controls are positioned on a new up-front control panel or on the throttle and stick (HOTAS), and new dual multi-purpose displays are fitted. BAe converted two FRS1s to serve as prototypes, and the first (ZA195) flew at Dunsfold on 19 September 1988. Whilst it was once intended that the last batch of nine aircraft of the 57 ordered would be produced to FRS2 standard, the programme did not progress fast enough to allow this to happen. As a result, current plans are for FRS2s to be produced by a modification programme, to start in October 1990, and a Ministry of Defence contract worth £170 million was awarded in December 1988. This covers the conversion of all the Navy FRS1 fleet (believed currently to number 42 aircraft), for delivery to the squadrons from the early 1990s. In addition to this, further production of new FRS2s to maintain frontline strength through the decade is more than a possibility.

Below:
HMS *Ark Royal* (RO7), the third and last of the Royal Navy's 'Invincible' class carriers and the first to have the definitive 12° ski-jump. Three Sea Harrier FRS1s of 801 Squadron are arranged on the flightdeck. *Crown Copyright*

Harrier II/AV-8B/GR5

The New Generation

The Harrier II is the aircraft with which the V/STOL fighter concept has truly come of age. A second-generation derivative of the Harrier GR3/AV-8A, the Harrier II is in almost every respect a new aircraft, which benefits from the first 15 years of service experience with its predecessors.

Development of the Harrier II – or AV-8B as it is known in US Marine Corps service – started as early as 1976, when the AV-8A had seen only five years of operations. The US Navy, on behalf of the US Marine Corps, placed a contract with McDonnell Douglas for prototype development of an improved Harrier, this being followed by a full-scale development contract in 1978. By this time, the AV-8A had proved itself ideally suited to the Marines' needs to provide a 'rapid response' CAS to the troops in the frontline, flying from rudimentary strips – 'grass ops' as they term them. Experience had shown the Harrier's V/STOL ability to be completely practical for this requirement, but the AV-8A did not have the payload range of contemporary aircraft. A big-winged Harrier derivative, employing some aerodynamic advances, modern constructional techniques and an uprated Pegasus seemed to offer the prospect of a far more capable aircraft.

Following the collapse of the joint UK/US studies in 1973/74 of the AV-16, an advanced Harrier development which was designed around a larger-fanned Pegasus 15 of considerably increased thrust, the two countries went their separate ways. McDonnell Douglas offered the US Marine Corps the AV-8B, whose major change was the incorporation of an all-new wing of increased span and area. The supercritical aerofoil chosen results in a thick section, which has the advantage of permitting a large increase in fuel tankage. To improve further the STO performance, large single-slotted flaps are fitted, and the whole structure – wing, flaps and ailerons – is constructed from carbon composite material, with a large reduction in weight. Increasing the span has allowed the fitting of six (rather than four) underwing stores stations, while the centreline station is retained. Further aerodynamic advantages in V/STOL flight result from the fitting of large longitudinal under-fuselage ventral strakes with a retractable dam between them, these improving gas recirculation in ground effect. A new front-fuselage was designed, with the pilot now benefiting from rearward vision over his shoulder as the result of a raised cockpit and a bubble canopy. Power is supplied by a Pegasus Mk 105, a derivative of the Mk 104 fitted to the Sea Harrier. Design aims for this engine are directed

Below:
ZD346, an early production GR5, is seen at the BAe flight test facility at Dunsfold, Surrey on 17 June 1988. Having just come off the production line, the aircraft is completely devoid of squadron markings, but it later became 'E' of No 233 OCU. *Author*

Above:
ZD327/D, one of the first four GR5s delivered to No 233 OCU in the spring of 1988. It is seen here on take-off from Wittering's runway on 18 August 1988. *Author*

Below:
The first US Marine Corps squadron to receive the AV-8B was VMAT-203, which took the first aircraft on strength in January 1984. Photographed at Cherry Point in August 1985, Lt-Col W. J. McAtee, XO of VMA-231, prepares to taxi for a conversion sortie in VMAT-203 AV-8B '25'. In the foreground are the US Marine Corps' first two woman AV-8B plane captains, L/Cpl Lauren Madda and L/Cpl Elaine Carter. *Author*

primarily towards reliability and maintainability rather than increased thrust, and a Digital Engine Control System (DECS) has been fitted to production engines from June 1986.

While the prototype YAV-8B – a modified AV-8A with the new wing but lacking the fuselage and cockpit changes of the definitive aircraft – made its first flight at St Louis in November 1978, BAe was meanwhile making its own 'big wing' design submissions to the RAF in response to ASR409. Like the US Marine Corps, the RAF wanted a 'second-generation' Harrier to replace the earlier aircraft in the mid-1980s. Both services were interested in a type with a primary air-ground capability, although the US Marine Corps requirement put a greater emphasis on a secondary air defence role. The accent was very much on improving STO performance, although the US Marine Corps had an additional requirement for VTO capability to mount a deck alert. BAe's proposals centred around a new large wing – called the 'tin wing' because of its conventional construction – which featured Leading Edge Root Extensions (LERX). Initially, it was intended that the RAF GR3 fleet would be rebuilt as part of a mid-life update, but this proposal became less attractive as time went on and the airframe hours on the GR3 increased. (By 1988, high-hour GR3s had over 4,000 airframe hours.) BAe's final proposals envisaged the building of 60 new aircraft with the big wing (these being referred to as GR5), but the economics of the programme for such a small run looked less and less attractive. Finally, under a Memor-

andum of Understanding signed in August 1981, the UK agreed to buy a developed AV-8B for the RAF and to abandon its independent 'big wing' projects. The RAF aircraft was given the designation Harrier GR5. If there was any one decision which saw the initiative for Harrier design move from one side of the Atlantic to the other, it was this one. McDonnell Douglas was named prime contractor for the AV-8B with BAe as principal sub-contractor. For the RAF's GR5, the situation was reversed, while the agreement also specified the workload breakdown for any export sales. To be fair, this was an eminently sensible agreement, which guaranteed a run of over 400 aircraft for the two countries (more than the whole Harrier programme up to that point) and ensured economies of scale. Two final assembly lines were set up – at St Louis, Missouri and Dunsfold, Surrey – although virtually all components were to be 'single sourced', with the resultant shipping of sub-assemblies across the Atlantic in both directions.

The flight testing of the first Full Scale Development (FSD) AV-8B started on 5 November 1981, to be followed in 1982 by the first Navy evaluation at Patuxent River. Despite the fact that a RAF pilot was involved in this evaluation, the programme was still at this stage very much an American affair, and as a result the US Marine Corps got the aircraft into frontline service four years before the RAF. MCAS Cherry Point was the station which received the early production AV-8B deliveries, these going to the training unit VMAT-203, with VMA-331 becoming the first frontline unit to transition. VMAT-203's training throughput, stable for many years, was dramatically increased to meet the squadron formation needs of the AV-8B. Until 1987, however, it was handicapped by the fact of having only six TAV-8A on strength, this aircraft being useful for the most basic conversion to V/STOL flying but unrepresentative of either the flying characteristics or the systems of the AV-8B. Not until the summer of 1987 did the arrival of the TAV-8B at Cherry Point give VMAT-203 a suitable two-seater, this finally allowing the remaining TAV-8As to take their place alongside the AV-8A/AV-8C at Davis Monthan.

VMA-331 stood up with AV-8B on 30 January 1985. (By comparison, the first of two UK DB aircraft, ZD315, only made its first flight on 30 April 1985.) It was followed by two other squadrons at Cherry Point (VMA-231 and VMA-542), after which (in summer 1986) the AV-8A/AV-8C was no longer in use at Cherry Point. The initial strength of each AV-8B squadron was 15 aircraft and 21 pilots, rather than the final establishment of 20 aircraft and 30 pilots – the US Marine Corps stipulates 1.5 pilots/aircraft as the ideal ratio. Deliveries then switched to the West Coast, where VMA-513 at MCAS Yuma stood down on AV-8C in August 1986, thus effectively removing the type from the inventory. Re-equipment plans are to form eight AV-8B squadrons, with four on the East Coast under MAG-32 and four on the West Coast with MAG-13. The handover of the 100th US Marine Corps AV-8B took place on 28 December 1987, at which time the fleet had logged close on 57,000hr and 47,000 flights. Deliveries are continuing to enable all eight squadrons to convert and commence operations with 15 aircraft, following which the frontline squadrons will be brought up to the full 20-aircraft strength.

VMA-331 conducted an extended deployment aboard the helicopter assault ship USS *Belleau Wood* from January to June 1987, during which the aircraft flew 951 sorties. Squadron deployments, either as detachments or at full squadron strength, have been made to Europe to participate in such exercises as 'Northern Wedding' and 'Bold Guard'. The AV-8B has a neat retractable refuelling probe, rather than the fixed device used on the AV-8A, although the whole probe and associated fairing can be fitted and removed as required. The AV-8B has become part of Marine Corps operations, and is already more numerically important than was the previous AV-8A/AV-8C force at its peak. New operational techniques are being developed. In

Below:
This head-on view of a GR5 shows the eight under-wing stations (unique to the RAF aircraft) and the extent to which the outrigger wheels have been moved inwards compared with the GR1. *BAe 853708*

Top:
The prototype of the Night Attack AV-8B is photographed carrying an impressive warload of Mk 82 500lb bombs, Maverick ASMs and the pod-mounted 25mm cannon. It was taking part in a three-month operational evaluation in spring 1988 from Twenty-nine Palms Marine Base, California. *McDonnell Douglas C22-446-15*

Above:
A formation of four AV-8Bs of VMA-331 'Bumblebees', seen in 1986 in the initial US Marine Corps colour scheme. Since mid-1985, AV-8Bs coming off the St Louis production line feature a wraparound camouflage pattern, which dispenses with the light grey undersurfaces. *BAe 8600685*

April 1986, AV-8Bs participated in a combined close air support exercise with US Army AH-64 Apache helicopters at Fort Hood. The helicopters were used to designate targets with their laser illuminators, the AV-8B dropping laser-guided bombs. Despite AV-8Bs currently having no night attack equipment, the results (ie 100% direct hits by day and over 90% by night) were judged outstandingly successful. In DACT with other US Navy types, AV-8Bs have achieved excellent results when the rules of engagement require a visual identification, but the non-radar aircraft is clearly at a huge disadvantage against such types as the F-14 outside this scenario.

RAF Harrier GR5s and US Marine Corps AV-8Bs have much in common, but there are a number of differences in the avionics fit. Starting with the equipment in common, the heart of the AV-8B's avionics is the Litton ASN-130 inertial navigation system, the Smiths HUD and the Hughes Angle Rate Bombing Set (ARBS). ARBS uses both TV and laser trackers through a single set of optics, and can be locked on to a target illuminated either by ground troops or a designator-equipped aircraft.

Hands-on-Throttle-and-Stick (HOTAS) allows the pilot to control virtually all the items required in a combat situation – weapons, manoeuvre flaps, ARBS, Sidewinder selection etc – without removing his hands from the stick. US Marine Corps and Spanish AV-8Bs are fitted with a General Electric GAU-12/U five-barrel 25mm rotary cannon, with the gun itself mounted in the left-hand pod and the ammunition in the right.

The RAF has replaced this gun in its GR5s with a pair of Aden cannon, but of a new 25mm design which is claimed to deliver three times the kinetic energy of the present 30mm design. Marconi Zeus internal ECM is fitted, along with ALE-40 chaff/flares in an underfuselage dispenser (as fitted to 'Corporate-modified' GR3s). Other changes specified by the RAF included the local strengthening of the panels on the wing leading edge and around the intake lips and the fitting of a Martin-Baker Type 12 ejection seat in place of the American Stencel. While all AV-8Bs have seven stores pylons (compared with five on all previous Harriers), the GR5 will have two extra wing pylons, designed to mount a pair of AIM-9 Sidewinders without taking up any of the existing stations. RAF aircraft will be fitted with a Ferranti moving map display, as used in the Tornado, and a new Missile Approach Warning (MAW) system from Plessey. All in all, RAF GR5s will be more comprehensively equipped than their US Marine Corps

Above:
ZD402, the Pegasus 11-61 demonstrator, which made its first flight in June 1989. This is the engine which will power US Marine Corps AV-8Bs produced from mid-1990, although the RAF has yet to decide to fit it to production GR5s. *BAe 8904028*

brethren, but at a cost both financial and in terms of commonality. The decision to abandon the LRMTS seeker in favour of ARBS was surprising, but probably taken for reasons of standardisation. The saga of the inertial navigation system for the GR5 is a sorry one, and a major reason for the type's slowness in coming into squadron service. Originally, the GR5 was to be fitted with a Ferranti FIN 1075 INS rather than the Litton ASN-130 in the AV-8B. Initial production aircraft were fitted with this equipment, but it has suffered problems of reliability in service, leading to a decision to purchase 32 ASN-130 for use in the GR5s delivered to the first squadrons to convert operationally to the new aircraft.

The second problem to beset GR5 development resulted from the loss of ZD325 on 22 October 1987, when the aircraft crashed into the sea to the southwest of Ireland after the BAe pilot had apparently made an involuntary ejection. Modifications have had to be made to the seat, and these have also taken time to incorporate. Total RAF orders stand at 96 aircraft (including the two DB GR5s), an additional batch of 34 having been announced on 20 April 1988. Taken together with planned US Marine Corps procurement of 328 (304 AV-8B and 24 TAV-8B) and the 12 EAV-8B for Spain, this gives a total of 436 Harrier IIs required by the three nations. From St Louis, 110 AV-8Bs had been delivered by the start of 1988, and a multi-year purchase agreed of 72 aircraft (63 AV-8B and nine TAV-8B) for FY 1989 through 1991. Production from Dunsfold is running at around 20 aircraft per year, but many of the aircraft coming off the line have been temporarily stored at Dunsfold or RAF Shawbury pending complete resolution of the problems previously mentioned.

Formal handover of the RAF's first GR5 was made at a ceremony at Dunsfold on 1 July 1987, when the logbooks of ZD324 were handed to ACM Sir Peter Harding, then C-in-C Strike Command. First RAF deliveries to Wittering were made in the summer of 1988, and No 233 OCU had eight on strength by October, while a further example was in use there by the maintenance school. At this point, deliveries switched to No 1 Squadron. Pilots of this squadron started their conversion to the GR5 with the OCU late in 1988, the programme involving considerable classroom study (much of which is computer-based training) but only 16 flights and a total time of around six weeks. With the GR5 programme now picking up speed, No 1 Squadron should be operational on the type by late 1989. The two RAF Germany squadrons have now started to convert, beginning with No 3 in May 1989. It is assumed that each of these frontline units will exchange its GR3s for GR5s on a one-for-one basis; thus No 1 will have a strength of 12 GR5s (and maintain its two flights), while the RAF Germany squadrons will maintain their three flights and 18 aircraft. With the conversion to the GR5, No 1 will lose its T4, with all Strike Command two-seaters being concentrated on the OCU. RAF Germany will allocate its two-seaters to a new Flight at Gütersloh. What is certain is that the RAF has not at present placed orders for the TAV-8B, although this may well happen in the future.

Two other developments for the AV-8B are under way. Both the US Marine Corps and RAF would like to extend use of the aircraft to night operations, and the night attack version will be available soon. For the RAF, GR5s from the 42nd production aircraft will be built to an interim standard. From the second batch (ie No 63 onwards), production aircraft will be fitted with a GEC Avionics Forward Looking Infra Red (FLIR) system, a new Smiths head up/head down system and revised cockpit displays compatible with Night Vision Goggles (NVG). Thus equipped, the aircraft will be designated GR7. The next step will be to bring the first 41 aircraft up to GR7 standard, following which the interim aircraft will be retrofitted. As to RAF designations, the pundit will note that 'odd' marks of Harrier have been single-seaters, while 'even' designations have been two-seaters. The T6 will be T4 with a refitted cockpit with night attack avionics, while the T10 designation has apparently been reserved for the (logical) purchase of a batch of TAV-8Bs. US Marine Corps AV-8Bs will be night-attack capable from aircraft No 167, and previous aircraft will be retrofitted.

The name 'Harrier Plus' has been coined for a radar-equipped AV-8B. Up to now, the Sea Harrier has been the only member of the family to carry a radar. Harrier Plus will be fitted with either the multi-mode APG-65 (as in the F-18) or Blue Vixen, and a Pegasus 11-61 of significantly increased thrust. Although the AV-8B's major customer, the US Marine Corps, has no official requirements for a radar-equipped version, such an aircraft would have a significantly enhanced capability in both air-air and anti-shipping roles. More importantly for McDonnell Douglas and BAe, the availability of Harrier Plus would certainly widen the export market prospects, and the Italian Navy – which needs V/STOL aircraft of the Harrier family to operate from its *Giuseppe Garibaldi* aircraft carrier – could well be the first customer if the project gets a firm go-ahead.

Individual Aircraft Histories

This listing aims to give an outline service history of each of the Harriers built for the RAF and FAA, from GR1 through Sea Harrier FRS1 to T4A. The GR5, which has only just entered squadron service, has not been included; neither have the export aircraft. Reference to many sources of information – most of them unofficial – has been made in this compilation. The listing is not comprehensive; rather, it gives observations of each aircraft at certain points in its life, although an attempt has been made to record the major events. No claim is made that the contents are 100% accurate, although a great deal of research and cross-checking have been done. To wait for the certainty that every item of information was correct would preclude such a listing from ever seeing the light of day.

A note on the presentation. A date in brackets, eg (10/75), is an 'observation', ie when an aircraft was noted. A date presented in the style 25-12-85 or 12-85 is an 'absolute' date, ie the date on which an event happened. In the case of RAF and FAA Harriers, aircraft codes and squdron/unit 'ownership' are presented as 'S/4' or '001/801', ie the aircraft was coded 'S' of No 4 Squadron, or '001' of 801 Squadron. Squadrons and units mentioned include:

● *RAF*

Nos 1, 3, 4 and 20 Squadrons. No 233 Operational Conversion Unit. The Strike Attack Operational Evaluation Unit (SAOEU). Harrier Detachment, Port Stanley, later No 1453 Flight. No 1417 Flight, Belize.

● *Fleet Air Arm*

Nos 700A, 800, 801, 809, 899 Squadrons. Codes worn by Sea Harriers are noted in the listing; no attempt is made to indicate the 'base' tail codes indicating ship or shore base.

● For the record, Sea Harriers have carried:

H – HMS *Hermes*
L – HMS *Illustrious*
N – HMS *Invincible*
R – HMS *Ark Royal*
VL – HMS *Heron*, ie RNAS Yeovilton.

● References to St Athan are to visits to the Maintenance Unit, either for overhaul, rebuild or (in the case of many Sea Harriers) for storage.

● Other abbreviations used are:

A&AEE – Aeroplane & Armament Experimental Establishment, Boscombe Down
AAR – air-air refuelling
AMG – Air Maintenance Group. RNAS Yeovilton
BDRT – Battle Damage Repair Training
INTU – Indian Navy Training Unit
PEE – Proof and Experimental Establishment, Foulness
RAE – Royal Aircraft (now Aerospace) Establishment
wfu – withdrawn from use
w/o – written off

● *Development batch of six Harrier GR1s XV276-XV281, all used for development, trials etc – none to squadron service. First flights 8-66 to 7-67.*

XV276 Development flying Dunsfold. Appeared Hannover Show 1972. Crashed 10-4-73 Dunsfold.

XV277 Development flying Dunsfold. Stores clearance trials A&AEE, Boscombe Down (7-72). Martel trials. Rolls-Royce (R-R) Filton (still GR1) (6-87). Retired to AMG Yeovilton 30-11-88.

XV278 Development flying Dunsfold. LRMTS trial installation (72). wfu Gütersloh 11-85.

XV279 Development flying Dunsfold and Filton 1967-70. To A&AEE 6-73. Used for ground training Wittering. wfu Wittering as 8566M 12-85, still used as weapons trainer.

XV280 Development flying from 67. wfu 9-84, to PEE Foulness.

XV281 Development flying 67-81. A&AEE (6-70). Trials HMS *Eagle* 1970, A&AEE (12-84). wfu 87, ground instruction Wittering 6-88.

Harrier GR1

● *First production batch of 60 aircraft, XV738-XV762, XV776-XV810. Order placed 1966. First flights 12-67 – 9-71. Surviving aircraft converted to GR1A (early 70s), then to GR3 (mid-70s).*

XV738 GR1 later GR3. R-R Bristol trials (68). A&AEE Boscombe Down (2-72). B/3 (6-76), AB/3 (4-82), 15/1 (2-84). Experimental grey camo, 4 Sqn (2-84), B/4 with red/yellow/black fin (12-87).

XV739 GR1 later GR1A. A Sqn A&AEE (8-68), V/1 (73). Crashed Episkopi, Cyprus, 24-9-73.

XV740 GR1 later GR3. A Sqn A&AEE (4-71), CA/4 (4-75), A/4 (2-84), 05/1 (6-87), wfu 11-88.

XV741 GR1 later GR3. A Sqn A&AEE (8-68). Transatlantic Air Race 5-69. 4 Sqn (8-72), 01/3 (10-72), A/3 (6-76), A/233 (12/84), L/233 (12-88).

XV742 GR1-later GR3. HSA Dunsfold, painted USMC colours, later G-VSTO for Swiss AF demo. 11/1 (9-82). 28-10-83 I/233 crashed on Holbeach Range, w/o.

XV743 GR1. First flight 19-12-68. Crashed Dunsfold 27-1-69, before delivery to RAF.

XV744 GR1 later GR3. Transatlantic Air Race 5-69. 1 Sqn, 233 OCU, 44/233 (8-72), D/233 (2-87), P/233 (12-88).

XV745 GR1 later GR3. To Wittering 1 Sqn, 45/233 (10-72), 27/233 (7-74). Mid-air collision with XV754, crashed Nantwich, 19-1-76, w/o.

XV746 GR1 later GR3. X/1, crashed and repaired, J/1 (4-71), K/1 (3-73), 08/1 crashed 125 miles south of Tromso, Norway 12/3/76, w/o.

XV747 GR1 later GR3. 29/233 (2-74), G/4 (2-79), 02/1 (5-85), G/233 (3-85). 11-11-87 crashed Wittering, w/o.

XV748 GR1 later GR3. A/1 (10-72), 37/233 (2-74), B/233 (7-79), 11/1 (8-85), 07/1 (12-87).

XV749 GR1. K/1 (1-71). Crashed into Wash 27-4-72, w/o.

XV750 GR1. To 1 Sqn. X/20 (1-73). Accident 6-4-70, rebuilt. 6/9/73 crashed near Roermond, Netherlands, w/o.

XV751 GR1 later GR3. 5-8-69 crashed short of runway, West Raynham, rebuilt. N/1 (2-71), 51/233 (6-71), A/1 (4-72), V/20 (10-73), M/3 (8-76), 08/1 (7-79), 01/1 (7-84), U/3 (6-88).

XV752 GR1 later GR3. 233 OCU (1-71), 03/1 (4-76), 04/1 (2-82), 02/1 (2-85), G/3 (6-87).

XV753 GR1 later GR3. Y/1 (11-70), G/1 (1-72), 53/233 (9-73), 31/233 (2-74), C/233 (7-79), M/233 (2-82), AE/3 (2-84), 06/1 (5-85). 17-3-88 wfu, delivered by road to Abingdon.

XV754 GR1 later GR3. Z/1 (11-70), J/1 (10-72), 07/1 (6-74). 19-1-76 w/o in collision with XV745, crashed near Nantwich.

XV755 GR1 later GR3. 55/233 (10-71), G/1 (2-73), 20/1 (12-73), 02/1 (3-83), M/233 (2-84), 07/1 (9-84), M/233 (1-85, 6-88).

XV756 GR1 later GR3. To 233 OCU (70), 34/233 (2-74), 26/1 (2-79), 8-11-79 26/1 crashed near Holbeach Range, Lincs. Remains still in scrapyard, Faygate, Sussex. (8-85).

XV757 GR1 later GR3. To 233 OCU, fire damage 15-10-69, rebuilt. D/233 (70), N/1 (8-71), 57/233 (9-72), 12/1 (8-74). 21-9-79 collided with XZ128, crashed Wisbech, Cambs, w/o.

XV758 GR1 later GR3. Flew from HMS *Bulwark* 9-68. 233 OCU (11-70), 58/233 (9-73), B/3 (7-74) 3-10-74 damaged landing accident at Wildenrath, rebuilt. V/3 (2-79), 16/1 (4-83), J/233 (2-84), V/3 (2-88).

XV759 GR1 later GR3. To 233 OCU (11-70), 59/233 (9-73), 40/233 (12-73), E/233 (1-84), 04/1 (4-84), H/233 (5-84), O/233 (10-88).

XV760 GR1 later GR3. To 233 OCU (11-70), 42/233 (12-73), E/233 (7-79), F/233 (2-82), C/4 (6-85), K/3 (3-88).

XV761 GR1 later GR3. To 233 OCU, 11/3 (4-73), B/4 (9-75), CB/4 (10-80). 28-10-80 w/o near Prum, West Germany.

XV762 GR1 later GR3. To 233 OCU, 62/233 (7-73), F/233 (7-79), G/233 (2-82), 37/1 (4-82) To South Atlantic AAR 5-82, to HMS *Hermes*. A/1453 Flt. w/o 19-11-83 in Falkland Islands.

XV776 GR1 later GR3. P/1 (11-70), 14/1 (6/74), 9-4-75 crashed Church Stretton, w/o.

XV777 GR1 W/1 (11-70). 1-5-72 crashed Wittering, w/o.

XV778 GR1 later GR3. S/1 (11-70), 16/1 (6-74), 1417 Flt (1-82). To South Atlantic AAR 5-82. To HMS *Hermes* as 16/1. 07/1 (2-84), 08/1 (8-85). 4,182 airframe hours at 8-88 – fleet leader?

XV779 GR1 later GR3. A/4 (11-70), Q/20 (1-73), P/3 (2-79), AB/3 (6-85), AA/3 (11-85), A/233 (11-86). Currently Wittering gate guardian.

XV780 GR1 later GR1A. B/4 (11-70), U/20 (11-71), B/4 (5-72). 27-6-72 crashed Wesel, West Germany, w/o.

XV781 GR1 later GR3. C/4 (11-70), O/20 (1-73), A/3 (8-73). 12-6-79 O/3 crashed on approach to Gütersloh, w/o.

XV782 GR1 later GR3. D/4 (11-70), C/4 (1-73), uncoded/1 (1-83), O/1453 Flt (9-83), F/4 (6-85), wfu by 9-88.

XV783 GR1 later GR3. E/4 (11-70), D/4 (1-73), O/233 (1-82), to Belize (2-82), E/233 (10-84), AE/3 (7-85), I/4 (1-87), N/233 (6-88).

XV784 GR1 later GR3. G/4 (11-70), E/4 (1-73), D/4 (2-79), 02/1 (5-85), D/4 (7-85), C/233 (10-85). Cat 5 accident 2-4-86, spares recovery, now BDRT as 8909M at Wittering.

XV785 GR1 later GR3. To 1 Sqn, Q/20 (6-71), F/4 (2-73), 26-3-74 crashed Wildenrath, w/o.

XV786 GR1 later GR3. R/20 (6-71), 02/1 (4-76), CV/4 (1-81), E/4 (12-86), S/3 (2-88).

XV787 GR1 later GR3. To 233 OCU, A/1 (6-73), 02/1 (8-74, 2-82). Intended for South Atlantic, but returned en route after technical problems 5-82. 22-3-83 w/o as H/Har Det in Falkland Islands.

XV788 GR1 later GR3. M/1 (6-71), 11/1 (8-74), 1-12-75 w/o Belize.

XV789 GR1 later GR3. G/4 (6-71), F/4 (9-78). 4-82 32/1 Sidewinder test firings at Valley. To South Atlantic AAR to HMS *Hermes* 5-82. 32/1 (7-82), Har Det (7-83), B/233 (12-86), 07/1 (3-87), wfu.

XV790 GR1 later GR3. H/4 (11-70), S/20 (1-73), S/4 (8-79), 14/1 (1-83), AP/3 (6-85). 2-11-87 collided with XZ136, Otterburn, w/o.

XV791 GR1 later GR1A. J/4 (6-71), W/20 (1-73), M/20 (7-73). 9-7-73 crashed Wildenrath, w/o.

XV792 GR1 later GR3. D/1 (11-70), 30-11-71 Cat 4 damage after landing accident, Norway. Rebuilt. N/3 (2-79). 14-10-80 AN/3 crashed at Gütersloh, w/o.

XV793 GR1 later GR3. To 233 OCU, N/20 (3-73), L/4 (4-80, 6-87). wfu, fuselage on dump at St Athan 11-88.

XV794 GR1. K/4, 4-5-72 w/o Hutten, West Germany.

XV795 GR1 later GR3. X/1 (6-71), F/1 (8-71), 05/1 (6-74), F/3 (7-79), Z/3 (4-80). Loaned to 233 OCU, w/o 23-2-83 coded AF/3, collided with T4 XW926 near Peterborough.

XV796 GR1. J/1. 6-10-70 w/o Ouston near Sunderland.

XV797 GR1 later GR1A. S/20 (6-71), H/4 (1-73). 23-1-74 crashed Vredepeel, Netherlands, w/o.

XV798 GR1. T/20 (6-71). 23-4-71 crashed on landing at Wildenrath, w/o.

XV799 GR1. To 233 OCU. 12-9-72 9/233 crashed Kyle of Lochalsh, Scotland, w/o.

XV800 GR1 later GR3. U/20 (6-71). 16-5-74 G/4 damaged beyond repair at Wildenrath, wfu.

XV801 GR1 later GR3. V/20 (6-71), M/4 (4-73). 15-12-78 Y/3 crashed Ennigerloh, West Germany, w/o.

XV802 GR1. XX/20 (6-71). 21-3-72 crashed Stadtoldendorf, West Germany, w/o.

XV803 GR1. Y/1 (8-71). 3-8-71 crashed near Huntingdon, w/o.

XV804 GR1 later GR3. To 233 OCU, 45/233 (12-73), J/233 (7-79), 1417 Flt (3-82), B/4 (2-84), AD/3 (4-84), 07/1 (1-85), D/3 (5-87, 5-88).

XV805 GR1 later GR3. Z/20 (1-72). 7-2-72 take-off accident Wildenrath. 3-7-73 crashed near Coesfeld, West Germany, w/o.

XV806 GR1 later GR3. Y/1 (1-73), H/4 (5-75), AB/3 (2-84), AN/3 (10-85), N/3 (3-88).

XV807 GR1 later GR3. To 233 OCU. Reported w/o Wittering 7-72 (reports of its demise exaggerated). 07/233 (9-72), 47/233 (9-74), H/3 (8-75), L/233 (7-79). 14-7-81 1417 Flt, crashed Belize, w/o.

XV808 GR1 later GR3. L/4 (6-71), T/20 (1-73), W/3 (6-79), L/233 (9-85, 6-88).

XV809 GR1 later GR3. W/20 (6-71), J/4 (1-73), 09/1 (11-82). AF/3 seen painted in experimental camo, dark green overall (2-84). Reverted to normal camo (7-85). 20-5-88 F/3 crashed on take-off, Gütersloh, w/o.

XV810 GR1 later GR3. X/20 (9-71), XX/20 (2-73), X/4 (2-79), A/233 (5-87), K/233 (1-88, 6-88).

Harrier T2

● *Two development aircraft, XW174 and XW175, first flights 4-69 and 7-69.*

XW174 T2 HSA Dunsfold. 4-6-69 crashed Salisbury Plain, w/o.

XW175 T2 later T4. HSA Dunsfold, le Bourget show 6-71. Converted to T4 and rebuilt 1986 as Vectored (thrust) Aircraft Advanced (flight) Control (VAAC) at CIT Cranfield, used Flight Systems Dept, RAE Bedford.

● *Harrier T2. First production batch 12 aircraft, XW264-XW272, XW925-XW927. First flights 10-69 – 6-72.*

XW264 T2. HSA Dunsfold. 11-6-70 w/o attempting landing Boscombe Down.

XW265 T2 later T2A, T4, T4A. To A&AEE Boscombe Down 6-70. V/233 (8-86, 6-88).

XW266 T2 later T2A, T4, T4A. To 1 Sqn 11-70. 51/233 (12-73) S/233 (6-79, 6-88).

XW267 T2 later T2A, T4. To 233 OCU. 52/233 (12-73), T/233 (7-79), SA/SAOEU Boscombe Down 7-88. 'Nightbird' trials.

XW268 T2 later T2A, T4, T4A. To 233 OCU 1-71. 68/233 (3-73), 54/233 (12-73), U/233 (7-79). Loaned Indian Navy Training Unit, Yeovilton 2-83 - 3-83. 12/1 (11-84), U/233 (12-84, 6-87).

XW269 T2 later T2A, T4. M/4 (6-71), TB/4 (3-73), 06/1 (7-80), AY/3 (7-85), X/233 (11-87), Y/4 (9-88).

XW270 T2 later T2A, T4. To 233 OCU (71), 56/233 (5/74), V/233 (7-79), 12/1 (12-83), T/4 (11-86, 6-88).

XW271 T2 later T2A, T4. T/1 (1-72), 17-1 (4-74), R/233 (7-79), Z/3 (1-88).

XW272 T2 later T2A, T4. P/20 (1/72), Z/3 (2-79). 29-6-82 Z/4 w/o on take-off from dispersed site, West Germany.

XW925 T2 later T2A, T4. To 233 OCU (1-72), 57/233 (7-74), 17/1 (7-79), 12/1 (12/82), V/233 (12-83), Y/4 (1-87), R/233 (5-87, 4-88), 14-6-89 crashed at Gütersloh, w/o.

XW926 Built T2A later T4. 12/3 (2-73), M/3 (8-73), 58/233 (6-76), X/233 (7-79). 23-2-83 collided with XV795 on training sortie from Wittering, crashed near Peterborough, w/o.

XW927 Built T2A later T4. 27/233 (7-72), 59/233 (12-73), Y/233 (7/79) detached Yeovilton 7-79 to 10-83. Y/233 (12-87), Y/3 (12-88).

● *Harrier GR1. XW630 single aircraft to replace XV743, which was destroyed prior to delivery. First flight 6-71.*

XW630 GR1 later GR3. T/20 (1-72), A/4 (1-73), G/3 (2-79), AG/3 (1-81), M/4 (2-85, 12-87).

● *Harrier GR1. Second production batch of 17 aircraft. XW763-XW770, XW916-XW924. First flights 6-71 – 1-72.*

XW763 GR1 later GR3. B/4 (1-73), K/3 (8/73), AK/3 (1-81), 02/1 (8-85). Major bird strike, repairs to intakes and front fuselage, 1988. 02/1 (11-88).

XW764 GR1 later GR3. 02/3 (2-73), C/3 (4-73), AC/3 (1-82), C/3 (12-87), returned to St Athan by road 9-88, wfu.

XW765 GR1 later GR3. 03/3 (4-73), D/3 (10-73), 12-3-80 D/3 crashed near Lampeter, Dyfed, w/o. Remains at Faygate.

XW766 GR1 later GR3. E/3 (1-73, 2-79). 4-10-79 E/3 crashed Davenburg, West Germany, w/o.

XW767 GR1 later GR3. 04/3 (2-73), F/3 (4-73), 33/233 (6-76), H/233 (7-79), 06/1 (2-82), 5-82 To South Atlantic AAR. 6-11-82 crashed into sea off Falklands while serving with Har Det, w/o.

XW768 GR1 later GR3. 05/3 (1-73), G/3 (10-73), O/4 (6-77), 08/1 (12-84), O/4 (10-85), N/4 (12-87).

XW769 GR1 later GR3. 06/3 (2-73), H/3 (4-73), P/20 (2-75), 24/1 (8-76), 1417 Flt Belize (1-83). 28-6-86 A/4 crashed Chièvres airshow Belgium, w/o.

XW770 GR1 later GR3. Seen HSA Dunsfold open day 6-72. Farnborough display 9-72.

10/3 (2-73), J/3 (4-73). 6-7-76 J/3 crashed at Borken, West Germany, w/o.

XW916 GR1 later GR3. 07/3 (1-73), K/3 (7-73), W/20 (10-73), W/4 (2-79). 17-6-86 W/4 crashed at Yeovilton. Spares recovery, wfu.

XW917 GR1 later GR3. L/3 (1-72), 08/3 (2-73), L/3 (4-73), 6-10-87 L/3 last operational flight, 3,634.5 airframe hours. Gütersloh gate guardian. On to pole 2-5-88.

XW918 GR1. To 4 Sqn 11-71. To 3 Sqn, crashed Tuschenbroich, West Germany, 12-1-72, w/o.

XW919 GR1 later GR3. To 233 OCU, B/1 (2-73), G/1 (3-73), 28-6-73 crashed Lyneham, rebuilt, 09/1 (7-79), 03/1 (5-80), 5-82 to South Atlantic AAR as 03-1. 12-6-82 damaged by small arms fire. 04/1 (11-88).

XW920 GR1 later GR1A. 20-6-72 3 Sqn crashed while on detachment to Decimomannu, w/o.

XW921 GR1 later GR3. To 3 Sqn, K/4 (8-73), Belize (1-79), P/233 (3-81), to Belize (1-82), V/4 (7-85), 8-8-88 E/3 crashed Gütersloh, w/o.

XW922 GR1 later GR3. B/1 (11-71), 22/233 (7-73), 49/233 (6-74), 6-9-75 accident at Yeovilton Air Day – inadvertent pilot ejection on ground. K/233 (7-79), B/233 (8-85), 19-11-85 w/o. Used at ROF Enfield for 25mm Aden (GR.5) cannon trials.

XW923 GR1 later GR3. Z/1 (11-71), 23/1 (5-74). 26-5-81 1417 Flt Belize, w/o.

XW924 GR1 later GR3. L/4 (1-73, 2/79), H/233 (2-82). 5-82 to South Atlantic AAR, 35/1 (7-82). B/Har Det (12-82), 01/1 (2-84), G/4 (7-85, 12-87).

● *Harrier T4. Two aircraft, XW933, XW934. First flights 5-73, 10-73.*

XW933 T2 later T4. P/20 (10/73), Q/4 (10-75), Q/3 (2-79). At Yeovilton with INTU 3-83 - 4-83. 18-2-85 AQ/3 w/o after collision with F-104G near Bad Rothenfelde, West Germany.

XW934 T2 later T4. 06/1 (6-74), W/233 (7-83), V/233 (11-85), 12/1 (11-86, 11-88).

● *Harrier GR3. Third production batch of 12 attrition aircraft – the first to be factory-fitted with Pegasus Mk 103. XZ128 - XZ139. First flights 1-76 – 1-77.*

XZ128 GR3. 15/1 (5-76). 21-9-79 collided with XV757, crashed Wisbech, Cambs, w/o.

XZ129 GR3. 29/1 (6-76). To South Atlantic AAR 5-82 as 29/1. M/Har Det (12-82), 6/1 (2-84), O/233 (1-86), 09/1 (9-86, 6-88).

XZ130 GR3. To 3 Sqn. 27/1 (7-79), to Har Det, Falklands 12-82. AH/3 (7-85), G/233 (6-88), H/3 (8-88). wfu Gütersloh, 1-89.

XZ131 GR3. M/4 (6-76, 2-84), 07/1 (5-85), N/233 (5-85), D/1417 Flt (6-87), N/233 (6-88), G/1417 Flt (10-88).

XZ132 GR3. To 3 Sqn. 04/1 (7-79), A/233 (1-82), 36/1 (2-82). 5-82 to South Atlantic AAR, no operational use due to fuel leaks. 04/1 (6-88), L/233 (8-88), C/4 (12-88).

XZ133 GR3. 32/233 (1-77), A/233 (7/79), P/233 (4-82), To South Atlantic AAR, 10-1 (5-82). Har Det (6-82), damaged in hangar collapse, Port Stanley 7-82, 10/1 (2-84, 6-88).

XZ134 GR3. J/3 (6-77), AJ/3 (1-82). 3-5-83 AJ/3 w/o after engine failure, crashed at Stormede, West Germany.

XZ135 GR3. P/4 (3-77), CP/4 (1-81). 3-6-84 P/4 crashed Grossostheim, West Germany during display, w/o. Cockpit section still with RAF Exhibition Flight Abingdon as 8842M.

XZ136 GR3. To 1 Sqn, A&AEE (9-85), AO/3 (1-87). 2-11-87 O/3 collided with XV790 Otterburn Ranges, w/o.

XZ137 GR3. E/4 (2-79). 18-7-79 E/4 crashed Giessen, West Germany, w/o.

XZ138 GR3. H/3 (6-77), AH/3 (1-82), 02/1 (6-84), V/1453 Flt (1-86), K/233 (2-86), 14/1 (1-88), 01/1 (6-88), wfu Wittering 1-89.

XZ139 GR3. Z/3 (8-77). 25-8-81 AZ/3 crashed near Ahlhorn, West Germany, w/o.

● *Harrier T4. Third production batch of four aircraft. XZ145-XZ147 and XZ445. XZ445 technically part of Royal Navy Sea Harrier order.*

XZ145 T4. T/3 (2-79). AT/3 (1-81), T/233 (5-85, 1-88).

XZ146 T4. CY/4 (9-81), Y/4 (4-82), W/233 (5-85, 6-87).

XZ147 T4 later T4A. Z/233 (7-79), 14/1 (8-88), S/233 (9-88).

XZ445 T4A (no laser nose, Pegasus Mk103), built to Navy contract but delivered to Wittering as Navy contribution to 233 OCU. Q/233 (6-79), AQ/3 (1-86), 723/899 (1-88, 7-88).

● *Sea Harrier FRS1. Development batch of three aircraft. XZ438-XZ440. First flights 12-78 – 6-79.*

XZ438 FRS1. Not the first aircraft to fly, see XZ450. A Sqn, A&AEE (4-82), fitted refuelling probe, 2 × 330gal tanks for AAR. 809 Sqn markings (4-82). 17-5-82 crashed on ski-jump take-off, Yeovilton, w/o.

XZ439 FRS1. A Sqn, A&AEE (3-82), Sidewinder trials, Valley (4-82). 809 Sqn (4-82), 899 Sqn (5-82), trials HMS *Illustrious* (7-82), returned to BAe for development 9-82. Believed second prototype FRS2.

XZ440 FRS1. A Sqn, A&AEE (3-82), 40/899 (6-82), Sidewinder trials (7-82), BAe Dunsfold (9-82), 123/800 (5-88), 126/800 (7-88).

● *Sea Harrier FRS1. First production batch of 31 aircraft. XZ450-XZ460, XZ491-XZ500, ZA174-ZA177, ZA190-ZA195. First flights 8-78 – 5-82.*

XZ450 FRS1. First Sea Harrier to fly 20-8-78. BAe Dunsfold. To South Atlantic on HMS *Hermes* coded 50/800 4-82. 4-5-82 shot down by AAA during CBU attack on Goose Green airfield, w/o.

XZ451 FRS1. 100/700A, 100/899 (8-80). To 801 Sqn. To South Atlantic on *Invincible* as 006/801. Canberra kill 1-5-82. Hercules kill 1-6-82. 000/801 (3-83), 712/899 (3-87), 123/800 (5-88). St Athan (6-88).

XZ452 FRS1. 101/700A (10-79), 711/899 (3-82), to 801. To South Atlantic on HMS *Invincible* still coded 711, later 00 , 801 4-82. 1-5-82 Mirage IIIE kill. 6-5-82 007/801 collided with XZ453, lost.

XZ453 FRS1. 105/700A (1-80), 105/899 (8-80), 715/899 (9-81). To South Atlantic on HMS *Invincible* 4-82, 6-5-82 009/801 w/o, see XZ452.

XZ454 FRS1. 250/800 (2-80). 1-12-80 crashed into English Channel while doing low pass over HMS *Invincible*, w/o.

XZ455 FRS1. 102/700A (11-79), 712/899 (3-82), 712/800 (4-82), to South Atlantic on HMS *Hermes*. 1-5-82 Dagger kill. 21-5-82 Dagger kill. 000/801 (7-82), 715/899 (4-83), 127/800 (9-83), 712/899 (5-88).

XZ456 FRS1. 103/700A (1-80), 103/899 (8-80), 713/899 (9-81). To 801 Sqn. To South Atlantic on HMS *Invincible*. 1-6-82 008/801 hit by ground fire over Port Stanley, crashed into sea.

XZ457 FRS1. 104/700A (1-80), 104/899 (8-80), 714/899 (9-81). To 800 Sqn. To South Atlantic on HMS *Hermes* as 14/800 (4-82). 21-5-82 Skyhawk kill. 24-5-82 two Dagger kills. 713/899 (9-83), 715/899 (9-84), 125/800 (4-88).

XZ458 FRS1. 251/800 (4-80), 124/800 (3-82). To 809 Sqn (4-82). To South Atlantic AAR, to *Atlantic Conveyor* (4-82). 007/801 (5-82), 259/809 (8-82) 715/899 (4-83) 1-12-84 with 800 Sqn w/o Fort William.

XZ459 FRS1. 252/800 (5-80). To 800 Sqn. To South Atlantic on HMS *Hermes* 4-82 as 25/800, 256/809 (8-82), 716/899 (4-83), 001/801 (11-84), 717/899 (7-88).

XZ460 FRS1. 253/800 (5-80), 126/800 (5-81). To South Atlantic on HMS *Hermes* 4-82. 9-5-82 attacked Argentine trawler *Narwal*. 710/899 (9-83), 125/800 (4-84), 122/800 (12-87), 719/899 (9-88).

XZ491 FRS1. 004/801 (3-81). To 809 Sqn 23-4-82. To South Atlantic AAR 4-82. 002/801 HMS *Invincible* 5-82. 258/809 HMS *Illustrious* 8-82. 005/801 (2-83), 711/899 (3-83), 000/801 (10-85). 16-4-86 crashed Scotland, w/o.

XZ492 FRS1. 254/800, 123/800 (5-81). To South Atlantic on HMS *Hermes*. 23/800 4-82. 21-5-82 Skyhawk kill. 001/899 (10-83), 714/899 (3-84), 125/800 (7-85), 128/800 (12-87).

XZ493 FRS1. 001/801 (2-81). To South Atlantic on HMS *Invincible*, 001/801 4-82, 123/800 (9-83), 713/899 (1-85), 006/801 (12-87), 716/899 (10-88).

XZ494 FRS1. 716/899 (11-81). To South Atlantic on HMS *Hermes* 4-82 as 16/899. 008/801 (9-82), 714/899 (9-83), 004/801 (2-87, 6-88).

XZ495 FRS1. 003/801 (3-81). To South Atlantic on HMS *Invincible* 003/801 4-82. To 800 Sqn, then 003/801 (10-85), 714/899 (3-87, 10-88).

XZ496 FRS1. 002/801 (3-81), 127/800 (7-81). To South Atlantic on HMS *Hermes* 127/800. 21-5-82 Skyhawk kill. 257/809 (7-82), 126/800 (7-83). 16-3-84 lost off Norwegian coast.

XZ497 FRS1. BAe Dunsfold 3-82, to 809 Sqn, 4/899 (5-82), trials HMS *Illustrious* 7-82. To BAe Dunsfold 8-82.

XZ498 FRS1. 005/801 3-82. To South Atlantic on HMS *Invincible* 4-82 as 005/801. 124/800 (9-83), 002/801 (7-85), 001/801 (6-88).

XZ499 FRS1. 002/801 (7-81), 000/801 (11-81), to 809 Sqn 8-4-82 as 000/809. To South Atlantic AAR 5-82, to HMS *Hermes* as 99/800 (5-82). 8-6-82 Skyhawk kill. 255/809 (7-82), 002/801 (2-83), 715/899 (12-87, 10-88).

XZ500 FRS1. 128/800 (8-81), 130/800 (11-81). To South Atlantic on HMS *Hermes* 130/800 (4-82). 21-5-82 Skyhawk kill. 252/809 (7-82). 15-6-83 127/800 crashed into the sea, w/o.

ZA174 FRS1. 002/801 (12-81), to 809 Sqn 8-4-82. To South Atlantic AAR 4-82. To HMS *Invincible* 000/801 (5-82). 29-5-82 lost, rolled off deck of HMS *Invincible* positioning for take-off in high seas.

ZA175 FRS1. To South Atlantic on HMS *Invincible* 004/801. 21-5-82 Dagger kill. 125/800 (2-84), 710/899 (5-84), 124/800 (1-85), 005/801 (6-86), 713/899 (10-88).

ZA176 FRS1. To St Athan from Yeovilton 1-82. To 809 Sqn 4-82. To South Atlantic AAR 4-82. To HMS *Hermes* 76/800 (5-82), 001/801 (3-83). 6-83 emergency landing on Spanish merchant vessel *Alraigo* (2,300 tons), after pilot got lost from HMS *Invincible* — smallest ship to date to carry a Harrier. 712/899 (12-83), 007/801 (1-88, 7-88).

ZA177 FRS1. To St Athan from Yeovilton 1-82. 809 Sqn (4-82), 252/809 (4-82). To South Atlantic AAR 5-82. To HMS *Hermes* 77/800. 8-6-82 Skyhawk kill. 711/899 (9-82). 21-1-83 711/899, w/o.

ZA190 FRS1. To St Athan from Yeovilton 1-82. To 809 Sqn 4-82. To South Atlantic AAR 4-82. To HMS *Invincible* 009/801 (5-82). 21-5-82 Dagger kill. 009/801 (11-82), 126/800 (5-82), 006/801 (9-87). 15-10-87 (also reported 18-10-87) w/o flying from HMS *Ark Royal*.

ZA191 FRS1. To St Athan from Yeovilton 1-82. To South Atlantic on HMS *Hermes* as 18/800 (4-82). Destroyed (with ZA192) Agusta A-109 helicopter 23-5-82. 253/809 (7-82), 712/899 (3-83), 123/800 (5-84), 129/800 (1-88, 7-88).

ZA192 FRS1. To St Athan from Yeovilton 3-82. To South Atlantic on HMS *Hermes* as 92/800 (4-82). 1-5-82 hit by ground fire, repaired. 23-5-82 A-109 kill (see ZA191). 23-5-82 crashed on take-off from HMS *Hermes*, w/o.

ZA193 FRS1. From St Athan to Yeovilton. To South Atlantic on HMS *Hermes* as 93/800 (4-82). 24-5-82 Dagger kill. 254/809 (7-82), 004/801 (1-83), 003/801 (2-87, 5-88).

ZA194 FRS1. First flight 23-4-82. To Yeovilton 28-4-82 for 809 Sqn. To South Atlantic AAR to HMS *Hermes* as 94/800 (4-82). 23-5-82 Dagger kill. 251/809 (7-82). 20-10-83 716/899 crashed near Dorchester, w/o.

ZA195 FRS1. 710/899 (9-84). Converted to FRS2 at Dunsfold. First flight as FRS2 19-9-88.

● *Harrier GR3. Fourth production batch of 24 attrition aircraft. XZ963-XZ973, XZ987-XZ999. First flights 3-80 – 5-82.*

XZ963 GR3. To 1 Sqn. 14/1 (7-80). To South Atlantic AAR, to HMS *Hermes* as 14/1 5-82. 30-5-82 hit by small arms fire, crashed into sea, w/o.

XZ964 GR3. 09/1 (7-80), P/233 (3-83), AW/3 (4-86), F/1417 Flt (1-87), P/233 (6-88), D/1417 Flt (10-88).

XZ965 GR3. AM/3 (1-81, 2-84, 6-87), M/3 (2-88).

XZ966 GR3. 01/1 (3-81), 05/1417 Flt (8-82), C/233 (12-82), C/1417 Flt (3-86), K/4 (4-86, 12-87).

XZ967 GR3. C/233 (3-81), 1417 Flt (9-82), 0/233 (5-84), AB/3 (4-86), B/3 (6-87, 7-88).

XZ968 GR3. CK/4 (9-81), K/4 (4-82), 01/1 (5-85), 1417 Flt (5-88).

XZ969 GR3. AS/3 (4-82), 01/1 (5-85), D/4 (12-85, 3-88).

XZ970 GR3. AR/3 (4-82), R/3 (5-87, 12-87).

XZ971 GR3. N/233 (7-82), G/1417 Flt (1-87, 3-88).

XZ972 GR3. L/233 (2-82), 33/1 (4-82), to Valley for Sidewinder trials 4-82. To South Atlantic 5-82 to HMS *Hermes*. 21-5-82 crashed after hit by SAM over Falklands — first 1 Sqn loss of conflict, w/o.

XZ973 GR3. J/233 (2-82), 12-2-82 crashed near Corwen, North Wales, w/o.

XZ987 GR3. AX/3 (4-82), 0/4 (11-85, 12-87).

XZ988 GR3. N/233 (2-82), 34/1 (4-82). To South Atlantic AAR 5-82, to HMS *Hermes*. 27-5-82 crashed after hit by ground fire while attacking Goose Green, w/o.

XZ989 GR3. 07/1, to A&AEE and Valley 4-82 for Sidewinder trials. To South Atlantic AAR 5-82, to HMS *Hermes*. 8-6-82 heavy landing Port San Carlos, spares recovery. Returned to UK 11-82, Cat 5 (w/o). Rear fuselage used BDRT RAFG 5-88.

XZ990 GR3. H/4 (4-82), I/4 (9-87), A/3 (12-88).

XZ991 GR3. AD/3 (4-82), 07/1 (4-84), A/233 (7-84), D/1417 Flt (12-86), P/4 (3-87), C/3 (12-88).

XZ992 GR3. 05/1 (2-82). To South Atlantic AAR 5-82, to HMS *Hermes*. Har Det (7-82). 05/1 (2-84). 29-11-84 1453 Flt, crashed near Port Stanley, Falkland Islands, w/o.

XZ993 GR3. AU/3 (7-82), 1453 Flt (9-83), 04/1 (5-84), 11/1 (11-86, 6-88), M/4 (1-89).

XZ994 GR3. I/233 (4-82), F/233 (3-85), C/1417 Flt (3-88), returned to Wittering 11-88.

XZ995 GR3. AO/3 (7-82), B/233 (4-86), V/4 (3-87), E/233 (4-87), J/3 (12-88).

XZ996 GR3. I/233 (2-82), 1417 Flt (4-82), C/233 (5-85), C/1417 Flt (1-87), X/4 (4-88).

XZ997 GR3. E/4 (4-82), 31/1 (4-82). To South Atlantic AAR 4-82, to HMS *Hermes*. Attacked Port Stanley airfield 24-5-82, LGB attack 13-6-82. To Har Det 7-82. E/4 (2-84), O/1453 Flt (11-85), E/233 (9-86), J/233 (3-88).

XZ998 GR3. J/233 (7-82), D/1417 Flt (10-84), J/233 (11-86), D/1417 Flt (3-88, 11-88).

XZ999 GR3. I/4 (2-84), M/233 (4-86), H/4 (6-87, 12-87).

● *Harrier T4. Fourth production batch of four aircraft. ZB600-ZB603.*

ZB600 T4. R/4 (2-84), to St Athan 4-87. Z/233 (6-88).

ZB601 T4. X/233 (2-84), Y/233 (2-88).

ZB602 T4. Y/233 (2-84), to St Athan 11-87.

ZB603 T4. AZ/3 (2-84), Z/3 (4-87), Q/233 (2-88).

● *Harrier T4N. Batch of three two-seaters for FAA, Pegasus Mk 104, non-LRMTS. ZB604-ZB606.*

ZB604 T4N. 717/899 (12-83), 720/899 (5-88).

ZB605 T4N. 718/899 (1-85), 721/899 (4-88).

ZB606 T4N. To 899 Sqn 6-1-84, 7-2-85 crashed Sticklebridge, Somerset, w/o.

● *Sea Harrier FRS1. Second production batch of 14 aircraft. ZD578-ZD582, ZD607-ZD615. Order 1-7-82.*

ZD578 FRS1. 125/800 (5-85), 711/899 (6-85), coded '200' for Le Bourget show 6-85. 125/800 (12-87). To Boscombe Down 10-88.

ZD579 FRS1. Delivered to Yeovilton 4-85. coded '200' for the Le Bourget show 6-85. 717/899 (8-85), 126/800 (4-87), 719/899 (7-88).

ZD580 FRS1. 004/801 (7-85), 716/899 (1-88, 9-88).

ZD581 FRS1. 721/899 (10-85), 718/899 (4-88, 7-88).

ZD582 FRS1. 124/800 (1-86), 127/800 (12-87, 1-89).

ZD607 FRS1. 712/899 (9-85), 123/800 (12-87), 006/801 (6-88, 1-89).

ZD608 FRS1. To St Athan 1-86. 002/801 (2-87), 000/801 (6-87), 710/899 (10-88, 1-89).

ZD609 FRS1. 123/800 (12-85), 122/800 (2-87), 712/899 (10-87), 000/801 (6-88, 12-88).

ZD610 FRS1. 711/899 (3-87, 12-88).

ZD611 FRS1. 001/801 (2-87), 717/899 (11-88).

ZD612 FRS1. 000/801 (2-87), 002/801 (4-87, 12-88).

ZD613 FRS1. 710/899 (3-87, 9-88).

ZD614 FRS1. 124/800 (2-87, 12-88).

ZD615 FRS1. 005/801 (1-88, 12-88).

● *Harrier GR3. Fifth and final production batch of four aircraft. ZD667-ZD670. 'Post-Falklands' order.*

ZD667 GR3. U/4 (11-86, 12-87).

ZD668 GR3. Delivered to Gütersloh from Dunsfold 12-86. J/4 (3-87, 12-87).

ZD669 GR3. Delivered to Gütersloh from Dunsfold 1-87. A/3 (3-87), I/4 (11-88).

ZD670 GR3. W/3 (1-87), P/4 (12-88).

● *Harrier T4. Fifth and final production batch of four aircraft. ZD990-ZD993.*

ZD990 T4. X/3 (12-87), T/233 (10-88).

ZD991 T4. S/4 (12-87).

ZD992 T4. P/233 (11-87), X/233 (12-88).

ZD993 T4. U/233 (2-88), T/233 (2-89).

● *Sea Harrier FRS1. Third production batch of nine aircraft. ZE690-ZE698. Ordered 9-84. Original plans were for some to be completed as FRS2; all were built as FRS1 and most went straight to St Athan from Dunsfold for storage.*

ZE690 FRS1. Stored at St Athan 5-88.

ZE691 FRS1. Stored at St Athan 5-88.

ZE692 FRS1. Stored at St Athan 5-88.

ZE693 FRS1. 5-1-88 to St Athan for storage.

ZE694 FRS1. 8-3-88 to St Athan for storage.

ZE695 FRS1. Stored at St Athan 5-88.

ZE696 FRS1. Stored at St Athan 5-88. 123/800 (8-88, 12-88).

ZE697 FRS1. 122/800 (6-88, 12-88).

ZE698 FRS1. 16-8-88 to St Athan for storage.

● *Oddities and out-of-sequence serials.*

XY125 AV-8A 158969, given RAF serial for demonstrations 1973. Later delivered to USMC.

ZA250 Harrier Mk 52. Two-seater owned by Hawker Siddeley/BAe, used as demonstrator. Also carried G-VTOL. Stored at Dunsfold 12-88. To Brooklands Museum 1989.

£6.95

ISBN 0-7110-1886-3